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SOME EXPERIENCES AND OBSERVATIONS IN THE TREATMENT OF ARTERIOVENOUS ANEURISMS BY THE INTRASACCULAR METHOD OF SUTURE (ENDO-ANEURISMORRHAPHY) WITH SPECIAL REFERENCE TO THE TRANSVENOUS ROUTE *

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I. Renewed interest in the treatment of arteriovenous aneurisms has been roused by the great frequency of these lesions in the experience of the late World War. The coincident injury of the artery with its companion vein or with its satellites has long since been recognized by military experts as one of the most frequent and characteristic injuries of the blood-vessels in modern warfare. But the late war has exceeded the records of all previous wars in the frequency of vascular injuries, and especially those of the bivascular type. The increasing incidence of vascular injuries was foreshadowed by the records of the Balkan campaign of 1912–1913 which immediately preceded the World War; but even the incomplete contributions from the military surgeons of the belligerent armies which have appeared in the surgical literature during the last four years would indicate that the incidence of these injuries, and especially of the arteriovenous lesions, has exceeded by far any forecast based upon the experience of previous wars.[1] This increase is

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* Read before the Southern Surgical Association, December 16, 1919.

[1] Pirogoff, one of the greatest military surgeons, admitted in 1864 that he had never seen a single case of arteriovenous aneurism that had been caused by gunshot wound, and this statement was in accord with the statistics of all the older wars. Thus we find Demme (1859), who served in the Italian campaigns, recorded 400 wounds of the blood-vessels without seeing a single arteriovenous aneurism. In 74 cases of traumatic aneurisms no arteriovenous aneurisms were recorded in the American Civil War (1860–64); nor in the Russo-Turkish wars (1877–78). During the Franco-Prussian War (1870–71), out of 44 traumatic aneurisms, only 8 arteriovenous cases are recorded on the German side. Bramman in his classic paper on arteriovenous aneurisms (1886) gives a brief description of 4 of these, which are included in his total of 157 arteriovenous aneurisms, 36 of which, or 40 per cent., were caused by phlebotomy. (E. Forgue, Rev. de Chirurg., Tome 54, ii, p. 1.)

With the advent of the hard-jacketed, high-velocity projectile and small-calibre rifle, the history of war aneurisms begins as a conspicuous feature of warfare. Traumatic aneurisms, including the arteriovenous, became familiar injuries in the South African, Spanish-American Wars and in the Philippines.

They figured still more in the Russo-Japanese War, and constituted nearly 2 per cent. of the total wounds in the Balkan conflict in 1913, which immediately preceded the late war.

accounted for by the great preponderance of the artillery and machine-gun fire, in which shrapnel, fragments of explosive bombs, shells, hand grenades, and the pointed bullet of the machine gun have had unprecedented sway as vulnerating bodies.[2] Some idea of the great frequency and importance of these vascular injuries can be gathered from the fact that in a single British casualty clearing station, during the early days of the first battle of the Somme, there were 277 wounds of individual vessels which, according to Hey and Bowlby, required special treatments (Bowlby, *British Med. Jnl.*, June, 1917, vol. i, p. 707). Okinczyc (*Jnl. de Chirurgie*, 1917, vol. xiv, p. 441), writing of his experience with a French ambulance at the front, reports that 24.7 per cent. of the wounded required special attention for injuries of the blood-vessels, and that in 36 per cent. of these the injuries were multiple, involving usually the arteries and veins. Gerulanos on the German side (*Beitrag. z. klin. Chirurg.*, Bd. 93, 1914–15) reported that of 2522 wounded soldiers who were brought to him at the base, 50, or only 2 per cent., required special attention for gunshot wounds of the large blood-vessels. In the military hospitals at the base the effect of the first-aid treatment at the front and in the lines of communication at once lowered the proportion of gunshot wounds of the blood-vessels to about 2 per cent.

R. Solomon (*Beitrag. z. klin. Chirurg.*, 1918, vol. cxii, pp. 369–410), reporting the German experiences at Frankfort, in Rehn's Hospital, states that in a total of 25,000 wounded, 490, or 1.96 per cent., were admitted for gunshot wounds of the blood-vessels.

In regard to the increased frequency of the arteriovenous aneurisms, Sir George Makins (" Gunshot Injuries of the Blood-vessels," London and New York, 1919) in an analysis of 272 traumatic (war) aneurisms, admitted to the London hospitals, found that 120 were arterial and 152 were arteriovenous; and that of the latter, 52, or a little over half, were simple or direct aneurismal varices. He, in accordance with the majority of observers, finds that these bivascular or arteriovenous injuries occur with greatest frequency (at the base hospitals) in the carotid, femoral, pop-

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[2] Chalier and Glénard (Les Grandes Blessures de Guerre, Rev. de Chirurgie, T. 51, January-June, 1916, p. 210) in an exhaustive study of 1500 wounded under their care at the front during November, 1914, to February, 1916, carefully recorded the nature of the vulnerating agent and found that a little over 50 per cent. of these were caused by rifle bullets, including machine-gun fire; and the artillery projectiles 42 per cent. (fragments of shells, 539; shrapnel, 73; caving in of trenches and shelters by bomb explosives, 16; and other causes attributed to artillery fire, 6, equals 634 cases, or 42 per cent.). Subsequently after the date of their publication they note that the proportion of artillery projectiles greatly increased as the war advanced. There were only 7 cases of bayonet wounds. Bier and Kuttner make the same observation on the German side.

In comparison, we find that in the Russo-Japanese conflict the casualties caused by small arms and bullets on the Japanese side were 83.5 per cent.; by artillery projectiles, 13.5 per cent. On the Russian side, small-rifle bullets caused 84.5 per cent. of the wounds; artillery and explosive projectiles, 14.5 per cent.

liteal, and axillary tracts—though at the front the tibial vessels are most frequently injured (26.6 per cent.), but as these occur coincidently with other complicating injuries (fractures) they are treated at the front and thereby eliminated from the base hospitals. The great excess of arteriovenous injuries in the neck is shown by the fact that of 57 aneurisms, 10 were arterial and 47 arteriovenous, or about 80 per cent. arteriovenous. And of the latter, 49 were varicose and 18 aneurismal varices. In the femoral group (common, superficial, and profunda), 170 injuries are recorded, of which 30 per cent. were arteriovenous. In the 41 recorded in the popliteal group, 20 were arterial and 21 arteriovenous. Of this group, 17 were varicose aneurisms and 4 aneurismal varices.

Swan (1917) recorded 176 war aneurisms, of which 40 were arteriovenous, roughly 38 per cent. arteriovenous.

W. McAdam Eccles (1916) reported 50 traumatic aneurisms, of which 30 were arterial and 20 arteriovenous.

Soubbotich (1916), as the result of his large experience with the Serbian army, found a preponderance of arterial aneurisms. Of 126 aneurisms, 84 were arterial and 42 arteriovenous.

Bier reported, early in the war (1915), 102 aneurisms, of which 45 arterial and 56 arteriovenous were operated upon. The arteriovenous predominated in the femoral tract, where the proportion was 33 arteriovenous to 28 arterial.

Kuttner (1916) stated, in his large experience, that the relative proportion was 45 per cent. arterial and 55 per cent. arteriovenous.

Hotz states his proportion of arteriovenous as 70 per cent. of the total number.

In a general way, it may be safely stated that of the traumatic war aneurisms, fully 50 per cent. involve both the artery and the satellite vein, and furthermore, that in fully 50 per cent. of the arteriovenous aneurisms the communication established between the vessels is of the simple *direct* fistulous type (aneurismal varices), and that in the remainder the wounded vessels communicate *indirectly* through a pseudo or adventitious sac.

It is well to note that while the great preponderance of artillery and explosive projectiles, fragments of shells, etc., has been responsible for the increase in the war wounds of the blood-vessels, it would appear that the greatest number of these, and especially of the bivascular injuries (particularly the direct arteriovenous fistula), are caused by the small pointed rifle or machine-gun bullets.

In the neck, Makins found that in 60 recorded injuries of the carotid vessels, 22 were caused by bullets and 38 by fragments of shells or bombs, often of very small size, which were retained in the tissues or in the psuedo-aneurismal sacs.

R. Solomon (1918) states that the pointed rifle bullet was responsible for 81 per cent. of the traumatic aneurisms observed in the Frankfort Clinic,

of which 82.5 per cent. were through-and-through perforations, and 17.5 per cent. were complicated with retained missiles.

By reviewing the general (German) literature of the war, Solomon finds that 74 per cent. of the traumatic aneurisms were caused by rifle bullets, and in 14 per cent. of these the missile was retained. Shrapnel was the cause of the aneurisms in this author's series in 55 per cent., in 29 per cent. of which the missile was retained; in 11 per cent. of the aneurisms caused by fragments of grenades and bombs, fragments were retained in 57 per cent. Only 4 per cent. of the aneurisms were caused by punctured (bayonet, sword) wounds, and *contusions* were responsible for 20 per cent., though in the general literature, contusions are credited with only 1½ per cent.

Donati (1917), basing himself on a much smaller Italian experience limited chiefly to the extremities, estimates that 40 per cent. of blood-vessel injuries were caused by rifle bullets.

From all of which we gather that the largest number of aneurisms are caused by the small rifle bullet when it speeds through the tissues with high velocity, leaving only a clean-cut, tunnelled perforation. On the other hand, the fragments of shells or explosive projectiles of low velocity are *retained* in the tissues in about 57 per cent. of the cases.

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II. It is not my purpose in this contribution to enter into a general discussion of the subject of arteriovenous aneurisms, or even attempt a systematic account of the methods of surgical treatment, especially as developed in the experience of the great war. Such an attempt would carry us far beyond the scope of this publication, which is intended to renew attention to the frequency and growing importance of a vascular injury which has become more than ever one of the most conspicuous features of the surgery of modern warfare.

I have, elsewhere, treated this very interesting lesion in its manifold and general phases (see Vascular Surgery, Chapter lx, vol. v, Keen's Surgery) and have dealt more fully with the developments consequent upon the vast experience of the late war in a general review of the war surgery of the heart and blood-vessels, which is to appear in a forthcoming supplementary volume of Keen's Surgery, now in press.

My object in this paper is to give a brief account of a group of personal experiences which illustrate the practical application of the intrasaccular method of suture, which I have so long devised and advocated for the cure of arterial aneurisms (endo-aneurismorrhaphy), and found equally advantageous in the cure of the most frequent types of the bivascular or arteriovenous aneurisms.[3]

III. There is no single method or technic that is applicable to all

[3] Much of the text which follows is a transcript of an article contributed to the Osler Anniversary Memorial Volume, and is here reproduced by permission of the Editors.

varieties of arteriovenous aneurisms as these are met in practice. There are, and always will be, cases in which the conservative principle of the suture, which aims at the restoration of the functional integrity of the blood-vessels, will have to yield, in the presence of insurmountable and forbidding anatomical and pathological conditions, to the radical methods of ligation and extirpation, which are to be regarded as conservative whenever they accomplish their purpose (cure) without sacrifice of limb or life. But the experience of the author confirms the opinion that by the adoption of new technical suggestions, such as exhibited in this paper, the opportunities for the application of a conservative technic can be much enlarged, thereby reducing very considerably the number of radical ligations and extirpations which are undoubtedly performed with unnecessary frequency and severity in the current practice of the day.

It would be well to premise a further consideration of this subject by stating that in dealing with the later suggestions presented in these personal experiences, we have in mind the treatment of the fully formed or established types of the mature arteriovenous lesions as distinguished from the primary or recent wounds of these vessels, when the question of primary hæmostasis for hemorrhage or the relief of rapidly spreading hæmatomas is the first consideration. Even in these, the principle of conserving the functional integrity of the injured vessels is to be seriously considered, and can be successfully met, in many instances, by the devices of conservative practice—such as end-to-end suture of the vessels, vascular grafts and intubation with paraffined glass or metallic tubes (Brewer's, Tuffier's, Lespinasse's *et al.*). But the technical problems are very different from those offered by the mature or established arteriovenous aneurisms, with which we are now concerned.

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If we were to study closely the morphology and pathological anatomy of the mature and fully established arteriovenous aneurisms, we would probably be able to differentiate more than fifteen varieties. These, however, can be grouped about the two fundamental types, which have been classical since the days of Hunter and Scarpa. These are the *aneurismal varix* (varix aneurysmaticus), and the *varicose aneurism* (aneurysma varicosum). The aneurismal varix, with its subvarieties, typifies the *direct* mode of arteriovenous anastomosis; the varicose aneurism, the *indirect* communication between the two vessels, through a common intermediary or "communicating" sac. In the aneurismal varix the arterial and venous wounds become agglutinated and adherent as a direct inosculation, following as an immediate or early sequel of the injury and an arteriovenous fistula is established after the small perivascular extravasation has been absorbed. Two important subvarieties of this type must be distinguished: (1) The true aneurismal varix which presupposes a varicose dilatation of the vein, constituting the true sac of

the aneurism, and which, owing to the progressive dilatation of the vein, may attain enormous proportions, not only at the seat of the anastomosis, but in older cases, far beyond the proximal and distal sides of the abnormal communication, owing to the yielding and incompetence of the valves; and (2) the simple arteriovenous fistula (*phlebartery* of Broca) in which there is no varicose dilatation except a general symmetrical enlargement or ampullar formation of the vein at the site of the fistula, where the dilatation is confined by the resistance of competent valves.

In the *varicose* aneurism, *as classically described,* the normal anatomical position of the vessels is disturbed; they do not lie side by side as in the aneurismal varices. The injury is followed by more or less extensive hemorrhage, which, being circumscribed by the resistance of the perivascular tissues, forms a well-defined pulsating hæmatoma and finally an encysted and clearly differentiated and well-walled sac, which is lined with endothelium continuous with that of the open mouths of the blood-vessels.

As above stated, it is customary to describe a varicose aneurism as an intermediary pseudo-sac formed adventitiously and interposed between the injured vessels, through which an indirect communication is established between the artery and vein. But contrary to this teaching all surgeons of experience will agree that the formation of this *intermediary* sac is an exceptional occurrence, whereas the presence of a well-defined sac into which the injured vessels open *separately* without any disturbance in their anatomical relations—the two vessels lying side by side—is a common occurrence. On opening such a sac and evacuating the clot, the two vessels will be seen at the bottom or at some part of the periphery of the cavity, plainly in relief, or faintly outlined under the fibroendothelial capsule, which, in old aneurisms, covers them like a veil. The orifices indicating the original seat of injury will show themselves in various ways; either as elliptical or slit-like openings lying parallel to each other, or in a quadruple group, two proximal and two distal, separated by an interval of variable length. The proximal orifices represent the cardiac and the distal the peripheral ends of the divided vessels. These different appearances depend upon the extent of the primary injury—whether a partial or a total division of the vessels is involved in the trauma. In some rare cases in which the vessels have been completely divided, there are, as Amussat first observed, only two recognizable openings leading into the sac, one for the artery and one for the vein, which indicate the cardiac or central ends of the divided blood-vessels, the peripheral ends having been occluded by organized thrombi and finally lost in the wall of the sac. It is more frequent, in our experience, to see a type of varicose aneurism, following partial division of the vessels, in which there is a common, fairly large sac, which when opened exhibits a smaller pocket formed by the sheath of the vessels. In the centre of this smaller cavity four orifices appear in close proximity, showing that the vessels have been injured tangentially and

simultaneously, either by stab or shot, causing no disturbance in their relations as they lie side by side in perfect apposition. The four orifices lie parallel to each other, two above and two below, and open directly into the smaller sac formed by the sheath which has been torn open, leaving a circular or elliptical opening which merges in its contour with the larger pseudo-sac formed by the primary hæmatoma (Figs. 2 and 3, illustrating the case of Walter E.).

The margins of the orifices in all types of arteriovenous aneurisms of mature formation (six or eight weeks and over) are usually thick and smooth and are covered by a glistening endothelium which merges and is continuous with the endothelial lining of the cyst-like cavity of the sac. The same blending or merging with the endothelial lining is observed in the fistulous communications existing in the direct arteriovenous lesions; a matter of importance, as this thickened and firm lining offers an excellent grip for the sutures which obliterate the anastomotic communications.

Another and most troublesome, but rarer, type is the arteriovenous aneurism in which the artery has been injured simultaneously with its two satellite veins. In these cases a venous sac or ampulla is formed on each side of the artery. The two venous sacs are usually asymmetrical, according to the different planes of resistance encountered in their development, one of these attaining large proportions and the dimensions of the other being only moderate.

In stab or punctured wounds the adventitious or common sac lies, usually, in front of the vessels, and in the gunshot wounds the sac more often lies behind them.

The following diagrams (Fig. 1), modified from Sir George Makins' " Gunshot Injuries of the Blood-vessels, 1919," give a clear idea of the relations of the blood-vessels to each other and to the adventitious sac, as they would appear on cross-section. They are in perfect accord with the clinical findings, not only as carefully studied in " war aneurisms " by Makins, but with the morphology of these aneurisms as observed by the writer in his civilian experience.

In other still rarer cases, more often met in civil practice (hunting accidents), and fortunately limited, usually, to the peripheral vessels of a secondary order (upper extremity), are those in which an artery of smaller magnitude is injured simultaneously with its venæ comites at many places by fine shot. In these cases, the condition imitates cirsoid aneurism, and the arteries and veins are mixed up in such inextricable confusion that extirpation is the only remedy; fortunately, they seldom attain dangerous proportions or cause serious disabilities and can be safely allowed to remain undisturbed.

Arteriovenous aneurisms with an *arterial* sac, in which the aneurism ruptures secondarily and pathologically (not traumatically) into a vein, is so great a rarity in surgical practice that it can well be relegated to the domain of pure pathology. It is practically only observed in the

thorax as a result of pathological conditions beginning on the arterial side (aortic aneurism opening into the vena cava, etc.).

IV. *Personal Experiences with the Suture of Arteriovenous Aneurisms.*—In a personal experience of over 204 surgical interventions upon the large blood-vessels, I find the record of 24 cases of arteriovenous injuries of various types. In this group I have utilized the principle of endo-aneurismorrhaphy in 12; *viz.*, common carotid, 1; external iliac, 1; the common and superficial femoral, 8; the peroneal vessels, 1; the subclavian, 1. All of these have made good recoveries, except the carotid aneurism, in which death occurred on the eighth day after the operation from coronary disease and pulmonary clot; and, in the iliac aneurism, in which death occurred from mesenteric thrombosis and gangrene of the bowel caused by prolonged compression of a loop of bowel by a powerful Doyen retractor which had been used in an extensive subperitoneal dissection to expose the iliac vessels. In neither case, as shown by autopsy, was the technic of the operation, as far as the vessels were concerned, responsible for the fatal termination, as the condition of the wound was found to be faultless. In the subclavian case, operated on September 3, 1900 (a young white farmer, aged twenty-four years), the artery, which had been perforated with a bullet in the second division, immediately behind the anterior scalene, had to be ligated on each side of the muscle; but the vein, which was surprisingly small, was sutured. The patient recovered but lost parts of his hand from arterial ischemia and necrosis. In this case the operation was performed only two weeks after the injury and illustrates the importance of the time element in developing the collateral circulation.[*]

Lateral Angiorrhaphy in Arteriovenous Hæmatoma.—In another case a man aged twenty-six years, operated at the Touro Infirmary on May 3, 1907, suffered a gunshot wound involving the femoral vessels in Hunter's canal and was operated about six weeks after the injury by separate lateral suture of each one of the orifices, leaving the lumen of each vessel pervious. The patient made an excellent recovery, with perfect functional result to the limb, notwithstanding his deplorable condition from many wounds, including multiple fractures of the lower jaw, which he had received in quelling a negro riot at Liberty, Miss. This procedure represents probably the oldest and undoubtedly the best known of the conservative operations that have been applied for the cure of arteriovenous aneurisms, and is an ideal method when it can be carried out. The experience of the present war has added a large number of such cases to the early list of the pioneers—Z. von Manteuffel (1895), femoral vessels; Cammagio (1898), femoral vessels; Gérard Marchant (1898), brachial vessels; Peugniez (1900), brachial vessels; Matas (1900), sub-

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[*] This case is fully reported by the author in a paper on "Traumatic Arteriovenous Aneurisms of the Subclavian Vessels" in the Transactions of the American Surgical Association, 1901, and in the Jnl. of the Am. Med. Ass'n, Jan. 11, 1902.
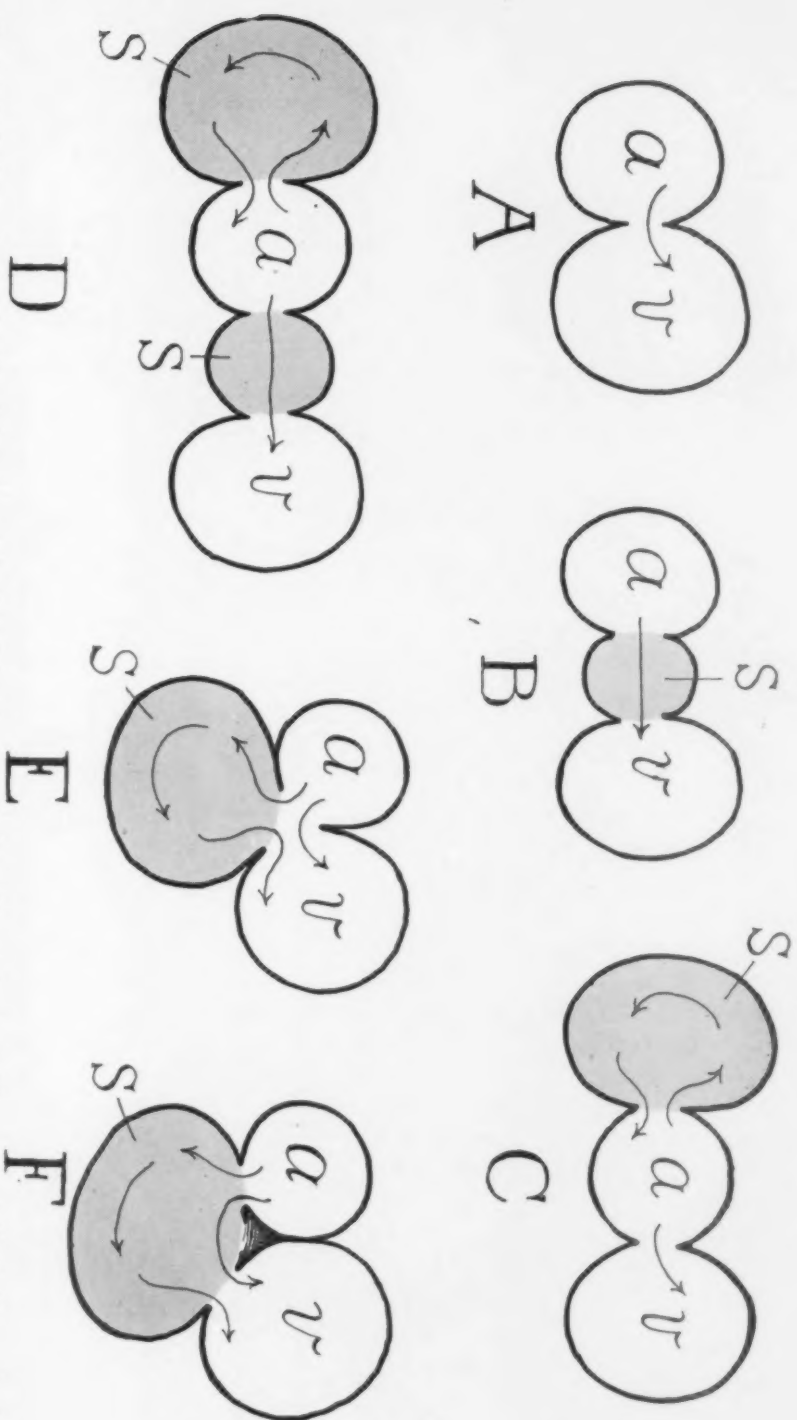
Fig. 1.—A, simple aneurismal varix. B, arteriovenous aneurism (so-called varicose aneurism) sac interposed. C, arterial aneurism combined with aneurismal varix. D, arterial and arteriovenous sac. E, arteriovenous sac with common opening of communication with artery and vein. F, arteriovenous sac with separate openings of communication with artery and vein. (Modified from Makins.)

FIG. 3.—Case of Walter E. Arteriovenous aneurism (so-called varicose aneurism); sac in front of femoral vessels. First step, obliteration of the orifices by separate suture. The interrupted suture is shown, closing the upper orifice, to the left, and the beginning of a continued suture at the right; as a rule, a continued suture is preferable, as it secures more perfect sealing of the orifices.

FIG. 2.—Case of Walter E. Traumatic arteriovenous aneurism (so-called varicose aneurism) with the communicating sac in front of the common femoral vessels (stab wound). Obliterative endo-aneurismorrhaphy by Doctor Matas, March 8, 1912. Vessels not completely divided and held by connecting bridge of the posterior wall which blends with the sac and is entirely covered by a smooth endothelial lining. The ridge in the centre indicates the remains of the vessel walls and septum.

Fig. 4.—Case of Walter E. Arteriovenous aneurism; sac in front of the vessels. Second step, obliteration of the false aneurismal sac by suturing the roof of the sac to the floor, without over-tension, to protect the primary orificial sutures, leaving a small area in the centre to be covered by the muscular aponeurotic layers as an additional protection. (See Fig. 5.)
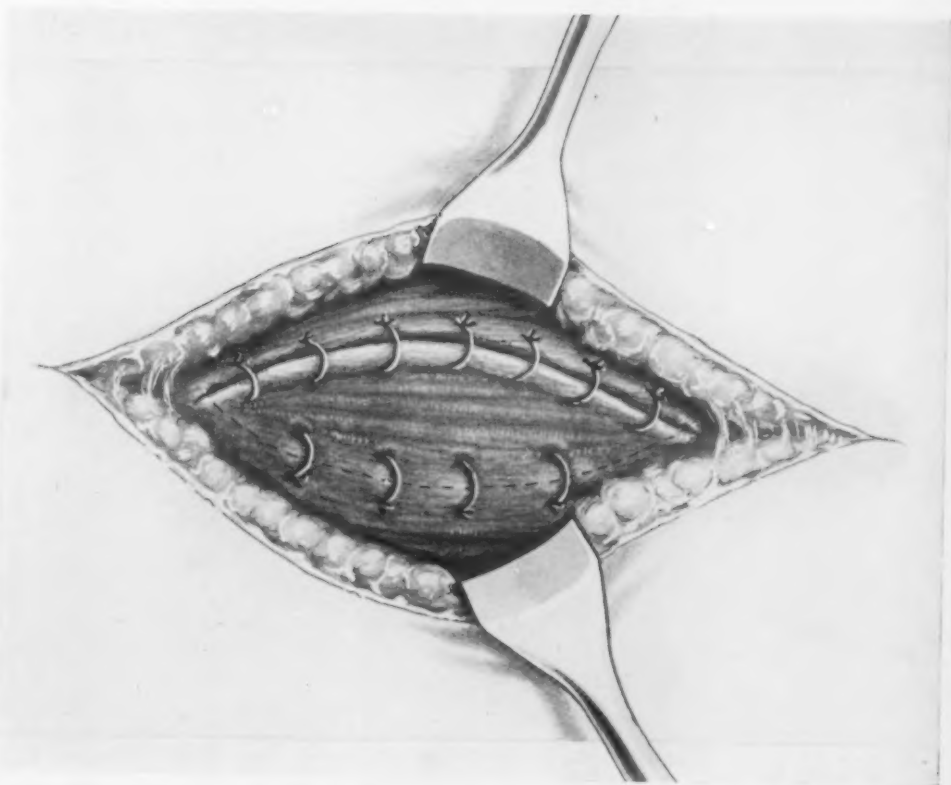
Fig. 5.—Case of Walter E. Arteriovenous aneurism. Third step, protecting second line of suture by overlapping musculo-aponeurotic planes, as in a hernioplasty. The suture of the skin and fat follows as the last step in the operation.
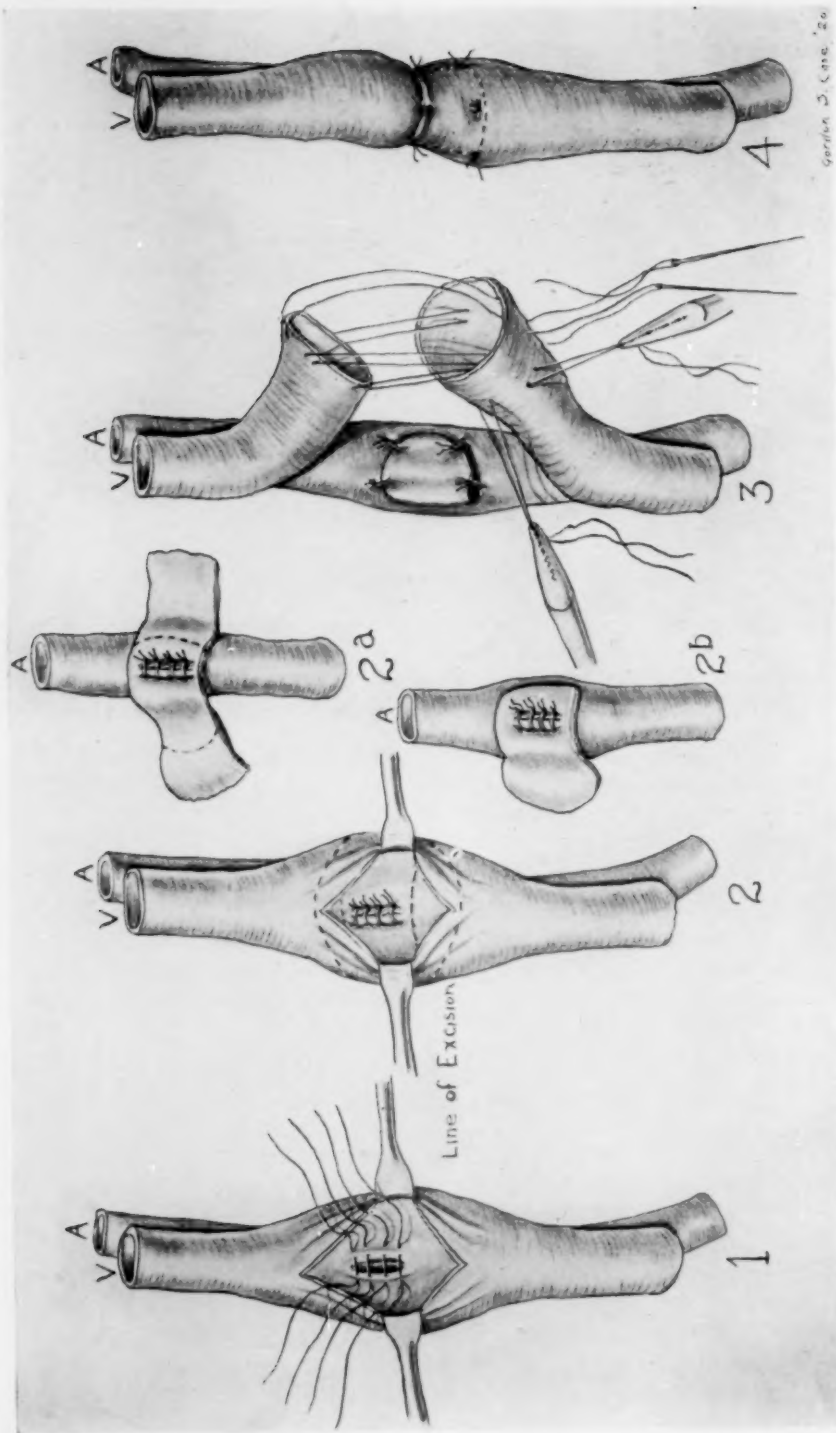
Fig. 6.—One of the methods of closing an arteriovenous fistula (aneurismal varix), by the transvenous route (Matas-Bickham procedure), modified by Dr. J. Chalmers Da Costa (Philadelphia, Pa.). See opposite page for explanatory note.

The diagrams (drawn from description) shown in Fig. 6 illustrate the procedure successfully adopted by Dr. J. C. Da Costa in the treatment of an aneurismal varix of the popliteal vessels. (ANNALS OF SURGERY, vol. lv, 1912, pp. 592–597.)

1. Longitudinal incision of the vein. Exposure and suture of the opening into the artery from within the veins.

2. The fistulous opening closed, the knots tied; dotted line of incision indicated to show extent of the circular resection of the vein.

2a. Flap of vein remaining attached to artery and sutured openings, lines indicating the extent of the paring of the venous flap.

2b. The venous flap reduced by paring remains adherent to the arterial wall with the movable flap ready to be turned over as a hinged cover to reinforce and protect the line of arteriovenous suture.

3. The venous flap is shown folded over the line of suture where it is held by a few interrupted sutures. The resected and dilated vein is shown in the act of invagination, with the transfixion sutures *in situ*, ready to telescope the proximal into the distal end. As a rule, the distal end should be invaginated into the proximal (cardiac) end in accordance with the direction of the venous current to diminish the friction of the blood stream against the cut edges—this should favor better apposition of the venous walls and also diminish the extent of the protecting parietal thrombus. It is also the rule of practice, at the present time, to unite the venous segments by the continued Carrel suture of the margins with confrontation of the endothelial surfaces, rather than by invagination by the Murphy method, which is now obsolete.

4. The venous anastomosis completed and the continuity of both vessels (artery and vein) restored with complete closure of the fistula.

In this procedure Da Costa found it necessary to modify the original Matas-Bickham procedure by cutting out circular section of the vein and utilizing this as a flap to cover and reinforce the line of arteriovenous suture, as shown in Bickham's diagrams (ANNALS OF SURGERY, May, 1904). The patch of the venous wall through which the fistula has been closed is alone excised and allowed to remain *in situ*, attached to the artery, and the oval gap remaining in the vein is closed from without by a continued suture. The longitudinal incision through which the fistula is closed is also sutured, and in this way the lumen of the vein is completely restored. Usually the vein is abnormally dilated and a plastic patch can be excised from its walls and the remaining gap sutured without constricting it unduly. In Da Costa's case the calibre of the vein had been so considerably reduced by the transvenous suture that he deemed it necessary to do a circular resection, as shown in the diagram, and the result was excellent.

[I have taken the liberty to substitute the present drawings for those which accompany Doctor Da Costa's original paper, believing that these will make the details of the procedure more intelligible.—R. M.]
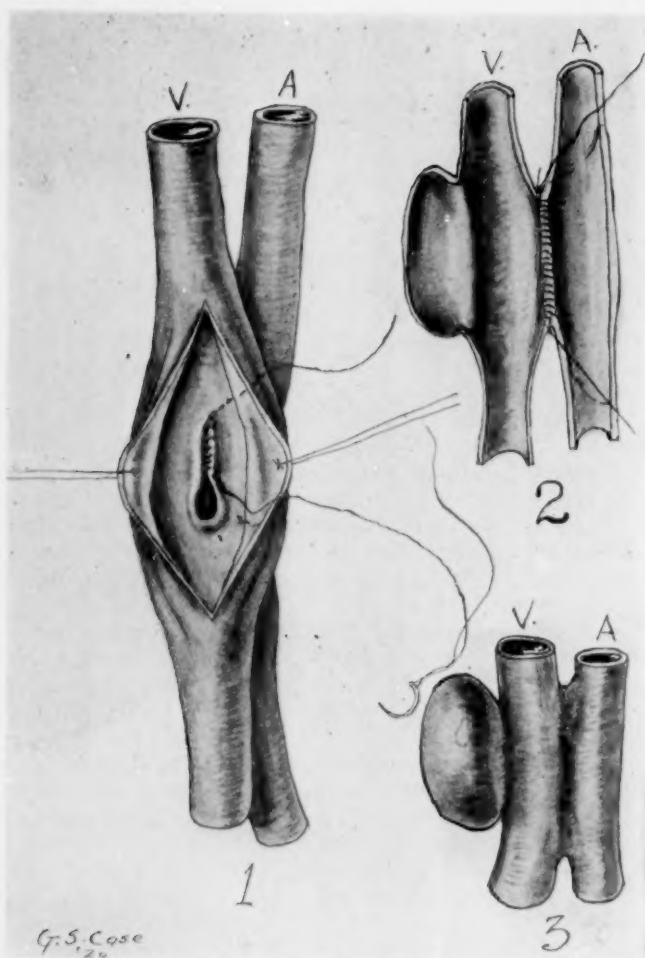
FIG. 7.—Closure of an arteriovenous fistula (aneurismal varix of the popliteal vessels) by the transvenous route (Matas-Bickham operation), with preservation of both vessels, leaving no knots in the lumen of the vein. These diagrams illustrate a recent successful clinical application of this method by Dr. William Pearson, Dublin (*British Med. Jour.*, June 14, 1919). 1, longitudinal incision of the vein with exposure of the arteriovenous orifice on the venous side. The arteriovenous stoma is being closed by a fine continued suture. No knot appears in the interior of the vessels. In practice the sutures are not exposed in the lumen of either vessel as much as figured. When the suture is drawn taut the thread line practically disappears with the edges of the orifice. The needle is introduced from the outside. 2 shows the continued suture closing the arteriovenous fistula, leaving no knots in the lumen, as viewed in cross-section. 3, diagram of the varix, showing the saccular dilatation of the vein opposite the fistula which was observed in Pearson's case. The sac was cut off and the fistula closed through the opening left by the excision. This method of endo-aneurismal suture without knots in the lumen is even better shown in Bickham's paper (ANNALS OF SURGERY, May, 1904). [These drawings have been copied from Dr. Pearson's original illustrations with modifications.—R. M.]

FIG. 8.—Case of John G.—jugulo-
carotid aneurism.

FIG. 9.—Case of John G.—jugulo-carotid
aneurism. Preliminary exposure of enormously
enlarged plexus of superficial pulsating
cervical veins.
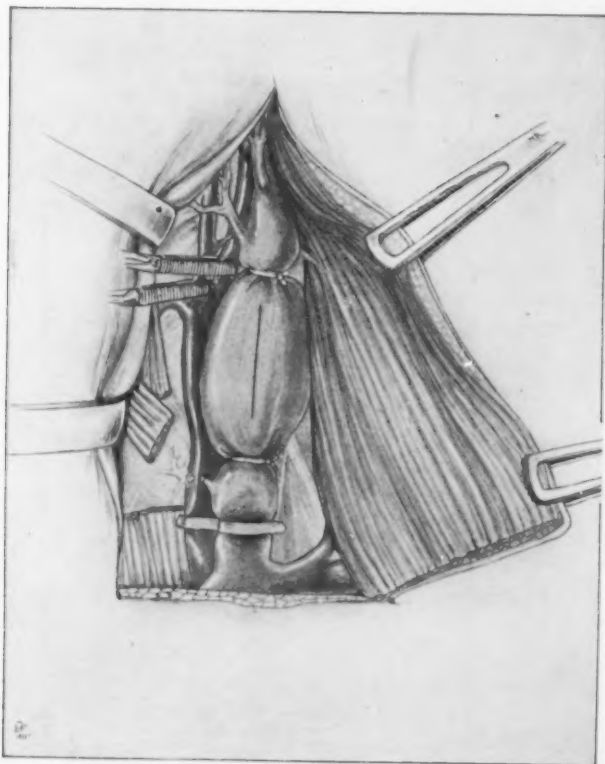
FIG. 10.—Case of John G. (jugulo-carotid aneurism), shows the dil-
ated jugular in relation with the carotid. With flat aluminum band
applied to jugular and to the common carotid; also two Hoepfner clamps
applied prophylactically on the internal and external carotids separately;
two catgut ligatures on the jugular above and below the arteriovenous
fistula; line of incision into the jugular to expose the arteriovenous
communication.

FIG. 12.—Interior of the sac exposed by opening the anterior venous wall. The method of obtaining hæmostatic control is shown. The single orifice of communication with thickened edges is closed by continued suture.

FIG. 11.—Diagrammatic representation of the arteriovenous communication between the carotid vessels in the case of John G. (jugulo-carotid aneurism).

clavian vessels, and to those of other civilian and military surgeons who had availed themselves of the progress in vascular suture long before the late war.

The Obliterative Suture in Arteriovenous Aneurism of the Varicose Type with Communicating Pseudo-sac.—Another case, operated on March 9, 1912, was that of Walter E., a youth of eighteen years, from Wesson, Miss., who had been accidentally stabbed when twelve years old, with a long pocket knife, in the upper femoral region. He had developed an arteriovenous aneurism which involved the common femoral vessels at the apex of Scarpa's triangle, close to the origin of the profunda. In view of the long duration of the aneurism and possible necessity of doing an obliterative operation, the boy was kept under careful observation for two weeks before the operation. During this time he was fed abundantly and given digitalis systematically, in the hope of increasing his blood-pressure which was scarcely ever over $\frac{110}{65}$. Frequent tests were made of his collateral circulation, which showed that the living color returned to the limb after Esmarch ischemia, while the common femoral was compressed. The living color returned in about five minutes, but just before the operation the time had shortened to three minutes. Feeling that a good collateral circulation had been established, I undertook the operation, believing that if it became necessary an obliteration could be performed without risk to the limb. The operation was performed under ether, at the Touro Infirmary, on March 9, 1912. The incision, directly into the sac, revealed a large well-lined cavity which was at first t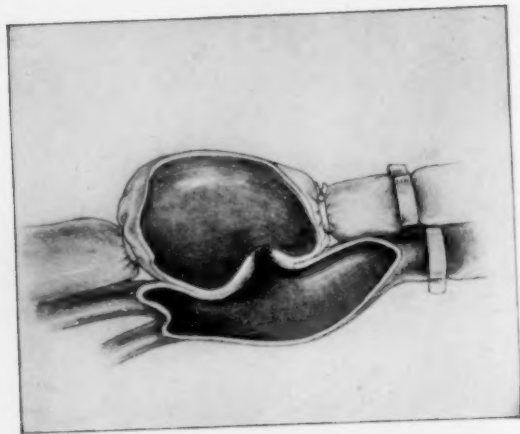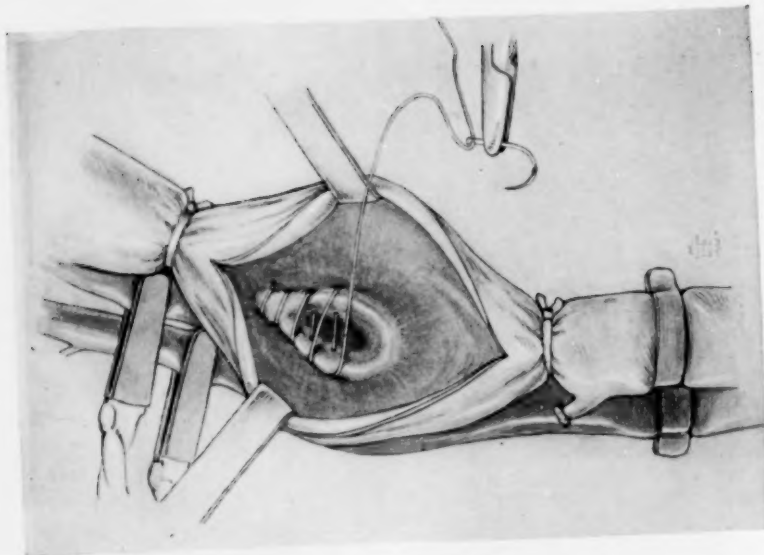aken to be the dilated femoral vein, but which was subsequently interpreted as a pseudo-sac well lined with endothelium which opened directly into a lesser pocket of oval shape, measuring about two inches in diameter (Figs. 2, 3, 4, and 5). At the bottom of this could be seen four separate orifices, each large enough to admit the tip of the little finger and grouped into a quadrilateral, the two openings on the inner side corresponding to the distal and proximal orifices of the femoral vein and the two outer to those of the artery. A ridge or linear induration indicated the original septum of the sheath which separated the arterial from the venous compartment, but the edges of the orifices were continuous and blended with the septum and with the smooth glistening endothelial surface that lined the interior of the sac. Each one of these orifices was now sutured separately with fine paraffined linen, leaving them completely sealed and obliterated. Then all communications leading from the large vessels to the sac were closed. The sac, which was very densely incrusted all over its walls with calcareous deposits in plaques, was only cleared of these incrustations by prolonged scrubbing with saline solution and gauze sponges. In the main cavity, which formed the bulk of the aneurism (size of a small apple), a mass of phleboliths was found in the midst of the red clot. After the toilet of the sac had been

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completed, this was obliterated partially by bringing the sac walls in apposition with continued rows of fine chromic gut sutures, in the manner shown in Figs. 4 and 5.

The blood-pressure before the operation (9.40 A.M.) was 110 S.; during the operation it rose to 120 S., and at the close of the operation (10.25 A.M.) it fell again to 110 S. At the close of the operation the Esmarch constrictor, which had been applied high up in the groin, was removed and was followed, in less than one minute, by a return of a good living color throughout the extremity to the tip of the toes. At 10.35 A.M. the dorsalis pedis and posterior tibial could be felt beating distinctly in the foot. Evidently the preliminary tests of the collateral circulation had told the truth, and the results confirmed our confidence in their value, and justified the obliterative operation which we had adopted.

The records show that the wound healed *per primam.* It was inspected on the fourth day. An ulcer which had existed in the leg as a consequence of the varicosities healed rapidly, and the boy was discharged and returned to his home on March 29, nineteen days after the operation, with his ulcer healed, a notable reduction in the varicosities, and perfect functional use of the limb.

Since the day of his discharge I have seen the boy repeatedly, and in my last examination, one year ago, there was no trace of the aneurism, and only a linear scar indicated the site of the operation. The varicosities along the saphenous tract had subsided, the ulcer had remained healed, and even the pigmentation which had darkened his leg had paled. He was working on a farm and doing hard labor as a field hand.

This case illustrates not only the simplicity and safety of the technic of the intrasaccular suture in its *obliterative* phases, but its successful application to a type of varicose aneurisms which is not infrequent and could be made quite formidable if attacked by followers of the methods of either one of the extreme and divergent schools of vascular surgery—the ultra-conservatives, represented on the one hand by the German followers of Lexer (in the early stages of the late war), who believe it their duty to do the so-called "ideale" operation in every case in which it was feasible and who, taking this case as an example, would have systematically extirpated the sac, dissecting out the vessels from their bed and attempted to do an end suture of both vessels,[5] and, on the other hand,

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[5] Early in the war, Bier, Küttner and other leading operators soon abandoned the extirpation of the sac in mature aneurisms as superfluous and unnecessarily traumatizing, and, in addition, dangerous to the collaterals—and thus got rid of one of the most objectionable features of the Lexer procedure. In lateral wounds, amounting to about 50 per cent. of the cases, they simply did an intrasaccular suture of the orifice of communication, precisely as I do a restorative endo-aneurismorrhaphy. In the complete sections of the vessels, when the vessels opened into the sac by separate orifices, they did a *transaccular* dissection of the divided vessel with careful and minute preservation of the collateral branches, and, after mobilizing the

the ultra-radicals, represented by the French school of surgeons who, following the lead of Delbet, extirpate the sac together with its vascular contents and then ligate the four stumps by the quadruple ligature.

Between these stand the intrasaccular ligaturists of the British and Japanese schools, who do far less damage to the perivascular tissues, but who, none the less, give themselves unnecessary worry and complicate their technic by dissecting out the main vessels and their collateral branches in order to close them by the quadruple ligature.

It is possible that by any one of these methods this aneurism would have been cured and the limb saved, because in this case it had been clearly demonstrated that the collateral circulation had been established and that restorative or reconstructive procedures were unnecessary. But why undertake a laborious and, at best, the uncertain circular angiorrhaphy, as in the so-called "ideale" operation, or subject the patient to the unnecessary trauma of an extirpation of the sac with its waste of good vascular material? Or, again, why insist upon the extrasaccular dissection by the quadruple ligature, when the simple obliteration of the orifices in the sac can be so often easily accomplished with the suture and with so much economy to the blood-vessels? Why not endeavor to attain the objective aimed at by the elementary and safe technic of the endo-aneurismal suture?

I could easily add to the testimony offered by the preceding case by a number of clinical experiences which prove the simplicity and reliability of the endo-aneurismal suture in the many phases of *varicose* aneurism in which the *obliterative* principle is indicated. Apart from my own experiences I could quote a number of confirmatory reports from the practice of my associates and other local surgeons (Doctors Gessner, Parham, Maes, Danna, and others) who have adopted the endo-aneurismal suture and successfully applied it in the treatment of arteriovenous lesions.

But I must proceed with the treatment of the most familiar type of arteriovenous injury, the *aneurismal varix* or fistula, which has furnished me with the largest and most varied experience in nine cases, in all of which I have applied the principle of endo-aneurismal suture in its *restorative*

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vessels, united the divided segments by a circular suture, leaving the sac intact. Küttner has gone much further than his contemporaries in utilizing attached sac flaps to patch extensive wounds of the arteries which were too large to allow of lateral arteriorrhaphy, thus avoiding whenever possible the necessity for a circular suture. In this way he has also utilized the principle of sac repair and arterial reconstruction far beyond the original scope contemplated by the writer in his reconstructive endo-aneurismorrhaphy. As a rule, in such extensive perforations I would apply the obliterative intrasaccular suture after testing the efficiency of the collateral circulation by previous tests.

In the course of the war the majority of German surgeons have virtually abandoned the method of grafting a venous segment to bridge the gap between the divided sections of the artery. They have found that this procedure did not justify by its results the time and labor expended in its performance. At any rate, it is largely recognized as a failure from the point of view of the practice of military surgery.

phases, with a success that could scarcely have been obtained by any one of the conservative or radical procedures in vogue.

In order to approach this subject more intelligently, a brief reference to the historical evolution of the special modification of the endo-aneurismal method as adapted to the peculiarities of *aneurismal varices* is necessary.

V. *Endo-aneurismal Suture by the Transvenous Route.*—In the ANNALS OF SURGERY for February, 1903, I published my first systematic account of the endo-aneurismal method of suture which I had first applied to a brachial aneurism on March 30, 1888 (*Medical News,* Philadelphia, October 27, 1888).

My paper dealt with arterial aneurisms and not with arteriovenous lesions, though the indications for the suture in these cases were obvious. This gap in the technic, however, was quickly filled by my friend and former associate, Dr. W. S. Bickham, of New York, who in an excellent paper published in the ANNALS OF SURGERY for May, 1904, suggested and elaborated a most ingenious technic for the application of the intrasaccular suture to the various lesions grouped together under the name of arteriovenous aneurisms.

The methods suggested and so clearly illustrated by Doctor Bickham in 1904 will be found more systematically described in his excellent " Text-book of Operative Surgery " (Third Edition, Saunders, 1908), under the heading of " Operations for the Radical Cure of Arteriovenous Aneurisms with Preservation of the Circulation in the Artery and Vein : The Matas-Bickham Operation."

Bickham's foresight and planning of this technic which was based upon the theoretical possibilities offered by the most familiar types of arteriovenous aneurisms are, indeed, most remarkable and praiseworthy.

The first clinical application of one of Bickham's suggestions, *viz.,* to attack the problem of closing the fistula in aneurismal varix by the transvenous route, was first demonstrated clinically by my friend and associate, Dr. H. B. Gessner (*N. O. Medical and Surgical Journal,* vol lx, 1907-8, pp. 553-556), in the case of a colored laborer, aged twenty-two years, who had sustained a gunshot injury (multiple small shot) in the abdomen and right thigh. The injury had been inflicted eleven years previously and involved the femoral vessels in Hunter's canal. The injury had caused comparatively little disturbance. The operation was performed on May 30, 1908. The sac itself was small and, notwithstanding the long duration of the injury, there were none of the varicosities or trophic changes in the skin of the lower extremity which characterize the progressive types of varix aneurismaticus. The thrill and murmur caused the patient anxiety and this was the chief reason for the intervention. In this case the sac was formed by ampullar dilatation of one of the venæ comites, the other being intact. Three arteriovenous fistulæ caused by small shot were discovered in the interior of the venous sac when this was opened. They were all closed by separate intrasaccular

sutures and the artery left undisturbed. The sac itself was folded and obliterated by suture.

The endo-aneurismal suture by the transvenous route was also utilized for the cure of aneurismal varix by Dr. J. Chalmers Da Costa of Philadelphia (ANNALS OF SURGERY, vol. lv, pp. 593–597, 1912). The operation was performed on October 22, 1910.

> The patient, a young woman, aged twenty-nine years, had been shot accidentally three months before the operation in the left popliteal space, with a No. 22 calibre bullet. Under ether, and after preliminary hæmostasis with Esmarch constrictor, the popliteal vessels were exposed and a longitudinal incision was made on the outer side of the vein. The fistulous opening which connected the two vessels was readily exposed and closed from *within* the vein with a No. o iodized catgut. On tying the sutures it was found that so much of the venous wall had been drawn in by the stitches that the calibre of the vein was greatly reduced. The vein was, therefore, divided transversely on each side of the point of fusion to the artery and a flap was cut out of the excluded venous segment and superimposed over the suture line in the artery and sewed to the artery by interrupted catgut sutures. Thus a flap of the vein was used to strengthen the line of suture at that point. The flap was about one inch in length. The two ends of the vein were then brought together by invaginating the upper (narrower) end into the larger (lower) end and fixed with four transfixion sutures, the line of junction being reinforced by a few catgut sutures passed through the external coat. The tourniquets were now removed and the blood jumped into both vessels, flowing through their respective channels, the artery pulsating vigorously and without a bit of leakage. The patient made an uneventful recovery. In a month she walked naturally (Fig. 6).

This very interesting case shows how the technic of a transvenous arteriorrhaphy or endo-aneurismorrhaphy can be ingeniously modified to meet the requirements of a conservative practice without affecting the fundamental principle involved in the procedure.

Another interesting illustration of the successful application of the transvenous method of closing an arteriovenous fistula by suture with the preservation of both vessels is furnished in the report of an aneurismal varix of the popliteal vessels, operated upon by Dr. William Pearson, surgeon to the Adelaide Hospital, Dublin, under the title of " Transvenous Aneurysmorrhaphy " (*British Medical Journal*, June 14, 1910, pp. 736–737).

> The operation was performed on January 15, 1917, on a soldier aged twenty-two years, who had been wounded with a rifle bullet on October 11, 1915 (nearly seventeen months before the operation). The popliteal vessels were exposed in the upper part of their course, where the artery and the vein were firmly adherent to one another without any intervening sac. Here the vein was greatly dilated and

the artery below was considerably smaller than usual. When freeing the side of the vein from its connection with the artery a saccular venous aneurism was exposed (see Fig. 7) and was removed, disclosing the arteriovenous stoma through the lumen of the vein. It was of an elongated elliptical form, one-half inch in length, and lying in the long axis of the vessel. The opening in the vein was enlarged very slightly upwards and downwards, and through it the aneurismal opening was sutured with a fine silk sterilized in liquid paraffin. The vein was then closed by continued suture. On removal of the tourniquet there was no bleeding, and the circulation through the vessels seemed perfect. The operation was completed by suture of the fascial tissue and the skin.

After the operation good pulsation was felt in the dorsalis pedis and posterior tibial arteries. On the following day there was no trace of œdema in the limb; the color was normal and the dilatation of the superficial veins had disappeared. Healing was uneventful, the circulation remained good, and the patient was allowed to walk four weeks after operation. He was kept under observation for two months and then discharged to light duty, the circulation being normal.

This case presents several unusual features apart from the technic employed to cure the aneurism—which can only be referred to in a cursory way, as the operative phase of the case is what concerns us in this paper. The fact that a distinct aneurismal sac formed opposite the fistula at the expense of the venous wall is rare; a general dilatation of the vein, often attaining enormous proportions, is common in old aneurismal varices, but a well-defined venous sac springing in an isolated fashion, as in this case, is not so frequent. When it exists, it lends, for obvious reasons, additional advantages to the transvenous method of suturing the orifice of communication. The fact, also, that in this case no signs of arterial varix developed until massage was applied to the limb, three months after the injury, is also instructive and justifies the opinion previously expressed by Pearson, that massage has proved an exciting cause of the rapid development of previously latent traumatic aneurisms in certain gunshot wounds of the blood-vessels.

The care taken by the author to avoid injury to the endothelium of the vein while exploring its interior as a preliminary to the transvenous suture by irrigating with warm saline instead of wiping the interior of the vein with gauze to clear the fistulous origin, and spraying with liquid vaseline, shows his appreciation of the dangers of thrombosis from rough swabbing of the endothelium.

But the method of introducing the suture to close the arteriovenous communication is most important. The needle is first passed through a small portion of the fibrous tissue which binds the vessels together at one end of the communication, on its external aspect (that is, entirely outside of the vessels and between the two), and does not penetrate the intima of either—it thus resembles the commencement of the outer row of sutures in a gastro-jejunostomy. This stitch is immediately tied and the needle is then passed obliquely from without inwards, emerging on the inner surface of the vein, close up to the extremity of the stoma (Fig. 7). The extreme edges of this are then brought together by fine

continuous suture through intima and media until the opposite end is reached, when the needle is again passed out from the lumen of the vein obliquely through its wall and the overlying tissue which binds it to the artery, so as to emerge between the two, when it is secured in a similar manner to the other end.

Thus it will be seen that there is no knot projecting in the lumen of either vessel, and if the stitches are placed accurately and drawn taut throughout, they do not present in the lumen of either vessel any more than in the case of ordinary through-and-through sutures. The closure of the incision in the vein presents no difficulty, being effected by continued suture which brings the opposed endothelial surfaces in confrontation. The result obtained by Pearson in this case is most gratifying, as it confirms the value of Bickham's excellent suggestion and my own personal experience with the transvenous method of aneurismorrhaphy in the treatment of aneurismal varices.

It is noteworthy that the technic described by Pearson, and which he appears to have worked up independently, is identical in principle and almost in every detail with that described and illustrated by Bickham in the ANNALS OF SURGERY for May, 1904, and in his Operative Surgery, third edition, 1908, p. 136, under the title of the " Matas-Bickham Operation," and also reproduced in my chapter on Vascular Surgery of Arteriovenous Aneurisms, Keen's Surgery, vol. v, pp. 308–909, 1909, where the identical method of passing the obliterative suture from without inwards, leaving no knots in the lumen, is shown in Fig. 104.

What is more important is to remember that, while the approach to the arteriovenous communication in aneurismal varices is accomplished by opening the vein, and the closure of the fistula is obtained by the suture of the orifice through the *interior* of the dilated vein, as the essential features of the method advocated by Bickham and myself—the final disposition of the vein will vary according to the anatomical conditions revealed in the course of the operation.

It is evident that the ideal to be aimed at is the preservation of both vessels, especially when dealing with the large trunks at the root of the neck and of the limbs; but when for any technical reason it is difficult or impossible to close the orifice of communication without sacrificing the vein, this should be done unhesitatingly if by this sacrifice the arterial lumen can be preserved, or the closure of the fistula better secured. The examples already given and the reports that follow will show how, in some cases, the vein can be preserved in its integrity after the transvenous suture, and how, in others, it has been found necessary to ligate the vein above and below the anastomosis, or obliterate it by plication or utilize the attached segment to protect the line of suture with a reinforcing patch or flap cut out of the venous wall.

VI. The following case illustrates the application of the transvenous method of endo-aneurismorrhaphy to a *varix aneurismaticus* of the jugulo-

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carotid vessels, in which the vein was obliterated by plication after the closure of the anastomosis, leaving the external and internal carotid circuit at the bifurcation open. This case shows all the evils that may follow a long-standing arteriovenous fistula as a result of the short circuiting of the carotid stream through the fistula with secondary overstrain and dilatation of the right heart. It was a most trying and forbidding case which I would never have dared to approach by any other procedure.

Arteriovenous Fistula (Gunshot of Fifteen Years' Standing) of the Jugulocarotid Tracts, at the Bifurcation. Obliteration of the Orifice of Communication by Direct Suture Applied by the Transvenous (Transjugular) Route, Leaving an Open Collateral Channel to the Brain via the External and Internal Carotids and the Bifurcation (Fig. 8).—The patient, John G., an intelligent negro barber, aged forty years, consulted me first on April 12, 1912. He had been shot in the neck fifteen years before he applied to me for relief of symptoms caused by an aneurismal varix which, in the course of these years, had led to an enormous dilatation of the jugular and all the tributary veins. The man had been shot in an altercation, with a revolver, at close range, and the bullet (38 calibre) had perforated the internal jugular and the common carotid on a level with the bifurcation. The bullet, as was discovered fifteen years after, had lodged in the back of the neck and could be seen, in the radiograph, behind the articular process of the third cervical vertebra. The hospital record shows that one hour after the injury he developed unmistakable signs of an arteriovenous communication, which persisted and gradually grew worse as time went on. Simultaneously with the bivascular injury the spinal cord had been wounded. From this injury he gradually recovered in the course of five years. Also, as an immediate sequel of this injury, he developed a traumatic meningitis with hyperpyrexia (107.6°), which kept him in a state of unconsciousness and delirium for fifteen days. He recovered slowly, but was finally discharged from the hospital, hemiplegic, with the aneurismal varix in full activity. Apart from the annoying thrill and great noise which he heard roaring in his head, he was fairly comfortable and was able, at the end of five years, to return to his trade as barber. It was not until about one year before his consultation with me that the aneurism, or, at least, the swelling in his neck, grew rapidly, and he began to suffer with dyspnœa and with " choking spells " whenever he made unusual muscular efforts. He then had to give up his work and go to bed. His history also showed that he had been a steady drinker and a syphilitic. He had a large dilated heart and aorta with an aortic obstructive murmur, an irregular pulse, and relatively low blood-pressure. He was a stout man, weighing over 212 pounds, and his neck was disproportionately large from the great turgescence and enormous dilatation and tortuosity of the superficial veins, which pulsated, purred, and thrilled like living things. He had also developed a left-sided
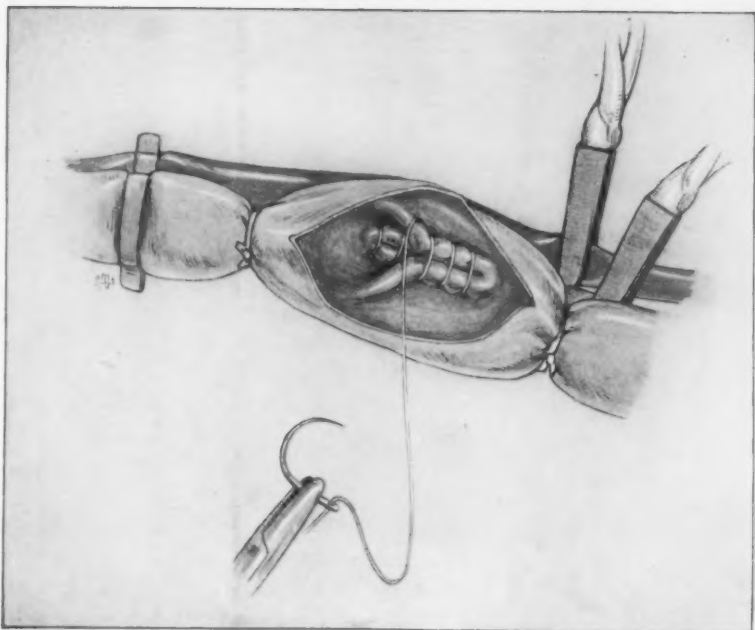
Fig. 13.—Obliteration of the sac by infolding and suturing the venous walls in superimposed layer after closure of the orifice.
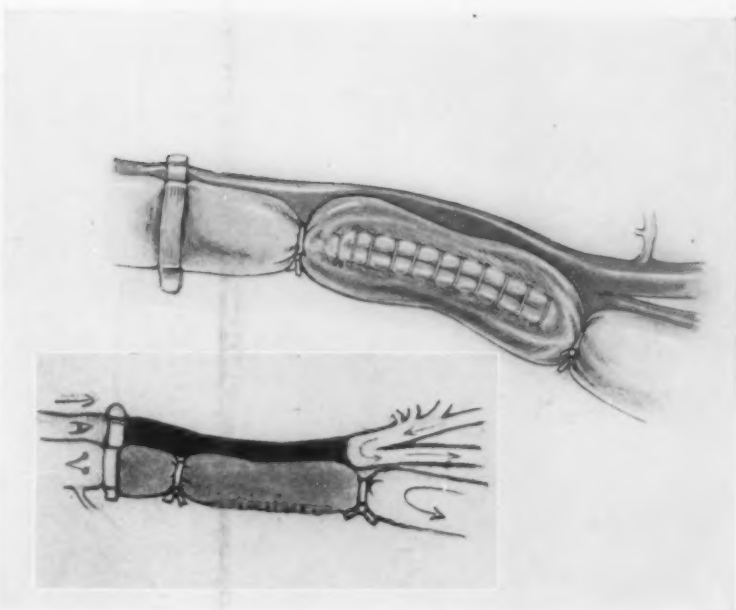
Fig. 14.—Case of John G.—jugulo-carotid aneurism. A shows the fistula closed and the incision into the vein sutured. An additional row of sutures followed this to completely obliterate the vein by infolding or plication. B shows the final result with the lesser collateral circulation maintained through the external and internal carotid and the bifurcation.

Fig. 16.—Iliac incision showing relations of external iliac vessels and anterior crural nerve, the finger pushing the enormously dilated vein aside. Case of J. H. H.—arteriovenous aneurism of common femoral vessels.

Anterior Crural Nerve.

External Iliac Artery.

External Iliac Vein.

Fig. 15.—External appearance of the left lower limb, showing varicosities and line of incision, also line of continued percutaneous suture to control bleeding from superficial abdominal plexus of veins. Case of J. H. H.—arteriovenous aneurism of the common femoral vessels.
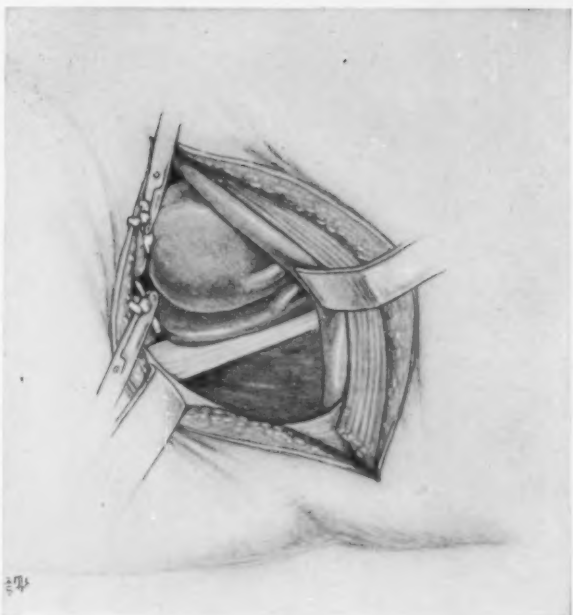
FIG. 17.—Same dissection showing artery controlled by provisional elastic ligatures.

FIG. 18.—Appearance of dissection above and below Poupart's ligament. Shows seat of the arteriovenous anastomosis and enormous enlargement of the vein.

Fig. 20.—Detail of anastomosis to show line of incision on the vein in order to expose the interior of the sac.

Fig. 19.—Deep dissection after division of Pourpart's ligament and methods of prophylactic hemostases before attempting the detachment and separate suture of the vessels.
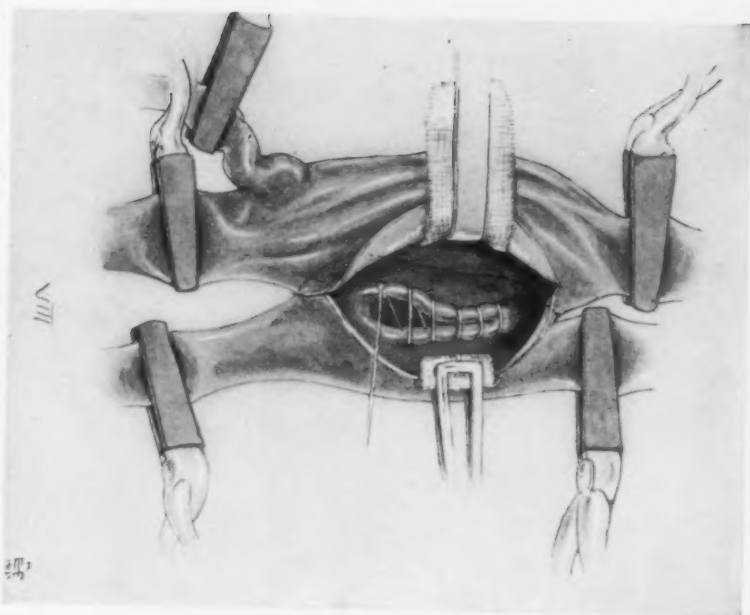
FIG. 21.—Interior of the sac, showing closure of the orifice of communi-
cation by continued silk suture.
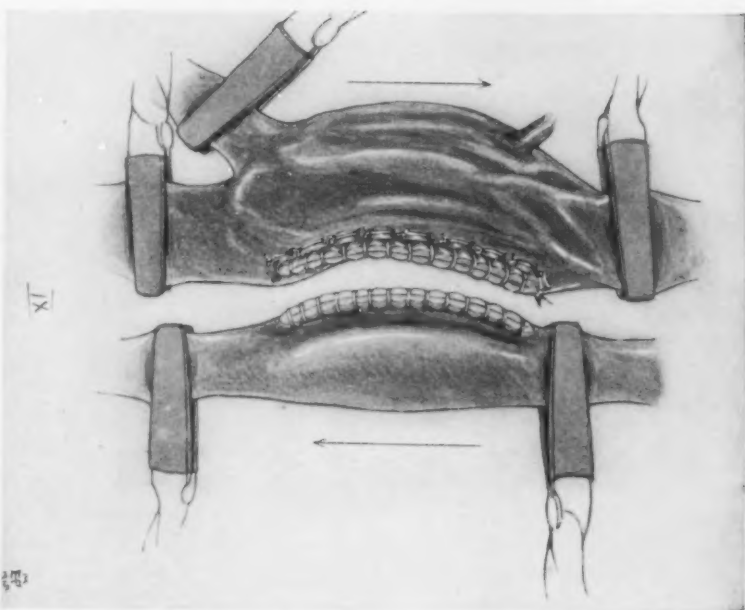
FIG. 22.—The anastomosis closed; artery and vein detached, isolated
and separately closed by lateral arterio- and phleborrhaphy. The arterial
orifice has been closed separately by intrasaccular suture on the venous
side and the first line of intrasaccular sutures is reinforced at the expense
of the vein.
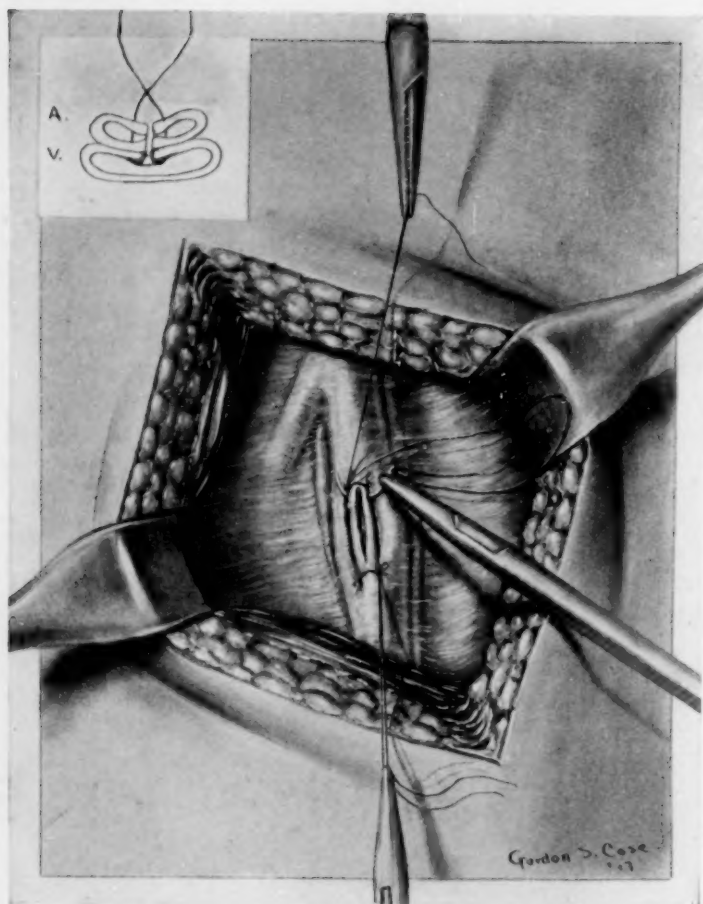
FIG. 23.—Case of Julius B.—Arteriovenous aneurism of the femoral vessels at the apex of Scarpa's triangle. Shows interior of large space occupied by hematoma, covered over with a veil of semitranslucent exudate in process or organization. First stage of the suture. In the upper diagram (a) the needle is shown penetrating through both walls of the artery and through the arteriovenous septum, so as to close the narrow fistula which connected both vessels. By lifting the walls of the collapsed and thin vessels with two traction sutures, one at each end, the curved needle was able to penetrate the septum and obliterate the orifice in the vein as shown in the sketch, (b) without obliterating its lumen.

exophthalmos caused by the dilatation of the retrobulbar veins, which gave him a very striking appearance (Fig. 8).

Whenever he exerted himself he was seized with a dyspnœa and a great anxiety, which he attributed to the aneurism, as the veins swelled and formed a collar which he said " strangled him."

At first, I would not consider an operation, because I believed the cardiovascular lesions were so advanced that they would soon prove fatal. However, after observing him for one month, it occurred to me that the dyspnœic spells were, in part, due to the great strain imposed upon the right heart by the constant inflow of the enormous stream of arterial blood which was being short-circuited from the arterial into the venous system, through the fistula, at the abnormal jugulocarotid junction. For nearly fifteen years his heart had been able to stand the strain by compensatory hypertrophy, but now, in consequence of myocardial degenerative changes, it yielded to the strain at the slightest provocation, and he was in constant danger of an acute dilatation. It seemed to me that if the fistula could be closed the great strain on the heart would be relieved and his general condition improved. Chiefly for this reason I yielded to his urgent solicitation, but with grave misgivings as to the outcome which he fully realized.

Operation.—I decided that I would operate in two stages. The first was to be limited to the clearing out of a great mass of superficial veins which were in the way and prevented a free access to the common carotid; then a removable aluminum band, of the type that we had been using for years for this purpose (Matas-Allen band), was to be placed on the artery with a view of testing the efficiency of the collateral circulation in the brain, through the circle of Willis. The first step was to end at this stage of the procedure; the wound was to be closed and the effect of the carotid occlusion on the brain was to be observed for several days. If no complications followed, the second stage was to be undertaken in a few days with a view of closing the arteriovenous fistula and curing the aneurism. This program was carried out to the letter, with some additions, on May 4, 1912. In view of the great dangers of general anæsthesia, the operation, in two stages, was performed under local and regional anæsthesia with novocain-adrenalin solution, preceded by a hypodermic of morphia gr. $\frac{1}{4}$ and scopolamin gr. 1/150. The difficulties of the operation were just as great as we had anticipated, and in completing its first stage, two hours and a half were consumed in one of the most difficult, tedious, and trying dissections that I can remember in all my surgical experience. We were greatly assisted, however, by the patient's stoic and even cheerful attitude. He never complained and helped us at all times by placing his head and neck in the most favorable position for our work. In this way we were able to clear the field of the immense pulsating and squirming plexus of veins which covered the entire field from the submaxillary region to the sternum and clavicle with very little loss of blood and with all the deliberation and neatness of a cadaveric dissection

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(Fig. 9). When this had been done the sternomastoid was divided at its sternal and clavicular attachments and reflected outwards, thereby exposing an immensely dilated jugular which completely overlapped and covered the carotid (Fig. 10). After dividing the omohyoid and sternohyoid, the site of the anastomosis was easily recognized as a cicatricial plug which could be felt over the mass that bound the carotid and jugular with the sheath of the vessels and held them together in an inextricable, fused, pulsating mass. Pressure at this point, which was the vortex of the great circulatory storm that raged in these parts, put an immediate stop to all pulsation and brought about the collapse of the veins. We availed ourselves of this subsidence in the venous swelling to clear out the common carotid and apply the aluminum band on this trunk at about one and a half inches above the left sternoclavicular joint. The seat of the anastomosis we had now located, with accurate precision, on a level with the bifurcation. On releasing the pressure at this point, the jugular filled again and pulsated, but very much less vigorously than before the banding of the carotid. In view of this greatly diminished activity of the arteriovenous circuit, an additional band was placed on the jugular about one inch from its junction with the subclavian. Seeing now that the vein became distended and pulsated to the level of the obstruction, a chromic catgut ligature was placed on the vein an inch and a half higher up, and that much nearer to the anastomosis. This reduced the size of the ampullar swelling very considerably, and, as the first stage of the operation had been completed, we decided to close the wound provisionally.

Notwithstanding the long and tedious ordeal, the patient was sent back to his bed in excellent condition, with a pulse of 100, respiration 22, and in a cheerful frame of mind.

In the absence of all complications, cerebral or otherwise, the second stage of the operation was undertaken on the third day after the operation, when the dressing was removed for the first time.

Second Stage.—On lifting the cutaneous flap the wound was found clean. The occlusion of the carotid and internal jugular had exercised a wonderful influence in diminishing the venous turgescence and erethism of the whole field of the operation. One significant fact remained: the arteriovenous fistula at the carotid bifurcation was still active. The pulsation and thrill could be still felt at this point, though greatly subdued. It was evident that the arteriovenous fistula was now fed by the arterial current which was coming from the collaterals of the opposite side through the external carotid to the internal carotid and again into the jugular through the fistula (Figs. 11 and 12). Evidently, the flow into the jugulocarotid fistula could not be stopped, or the aneurism cured, until the circulation going on through the external and internal carotids had been arrested. To accomplish this, these vessels were temporarily and individually compressed above their origin at the bifurcation with two small, padded Hoepfner clamps (Fig. 12). The internal

jugular was now ligated on the cephalic side of the arteriovenous junction. This made it safe to proceed with the next step of the operation, which was to open the jugular vein freely over the site of the fistula and thus expose the interior of its ampullar swelling and close the orifice of communication leading to the artery through the venous side. A longitudinal incision of about one and a half inches was made into the venous pouch through the collapsed walls of the vein. The orifice of the fistula was now brought to view. It was elongated, oval shaped, and a little over a half inch in its longest diameter. Beyond it the lumen of the enlarged carotid could be recognized, and by passing a vaselined probe, the orifices of the internal and external carotids could be felt arising a short distance beyond the edge of the opening. The opening itself seemed to occupy the centre of a partition or diaphragm, formed by the adherent walls of the artery and vein. There was no interposed space or sac between the two. The edges of the fistulous orifice were smooth and rounded, and just thick enough to give a good firm grip to the small curved needle and paraffined silk that was used to close it. Six continued sutures passed through the edges of the opening were quite sufficient to close it hermetically (Fig. 12). To secure further protection, a second line of continued chromic gut suture was made to cover the first line, by plicating the relaxed venous walls over it (Fig. 13). This reduced the cavity of the venous sac to a notable extent, but still left a very considerable excess of sac, which was partially trimmed off with scissors sufficiently to permit the complete obliteration of the cavity by infolding the edges of the vein and holding them in apposition ("capitonnage") by a continued gut suture. In this way what was once a large venous ampulla was transformed into a thick padded cord which completely obliterated the jugular from the proximal to the distal ligatures which had been previously placed on the vein, above and below the anastomosis (Fig. 14). The clamps were now removed from the external and internal carotids. It was soon determined that a reduced circulation had been established through these vessels, by way of the bifurcation, and that while the arteriovenous communication had been completely closed, a new channel for the arterial supply had remained. In this way, also, the main object of the operation had been obtained with a sacrifice of the vein, but with a greater conservative result on the arterial side than we had anticipated. This second sitting consumed, in all, about one and a half hours and was also carried out without any general anæsthetic, except a preliminary hypodermic of morphia and scopolamin. At the close, the wound was carefully dressed and drained at the lower angle.

All signs of the arteriovenous anastomosis had disappeared completely. From May 6 to 8 he continued to do well, only complaining of pain in swallowing. On dressing the wound on the 8th, evidences of suppuration and staphylococcal infection were discovered in the tract of the drain and several sutures were removed,

allowing some seropurulent fluid to escape. The infection had begun under the flap and a cellulitis was suspected between the lower carotid sheath and the pharynx. The pulse rose to 100 and showed more irregularity and intermittency. The mental attitude was perfectly clear and even cheerful; no evidences of cerebral disturbances. Dysphagia and occasional spells of dyspnœa were the chief troubles. The wound was dressed twice daily, and the infection seemed to be controlled. On the night of the 11th he became restless and anxious, and complained that he could not breathe comfortably and had to be propped up on pillows. On the morning of the 12th he washed his mouth and attended to his toilet as usual, but persisted in sitting up. At 8.30 A.M. he complained of sternocardiac pains and distress in the precordia and began to struggle for breath. The pulse now became very irregular and feeble and he expired suddenly before the interne of the service could reach him.

Death, therefore, occurred nine days after the first operation when the carotid and jugular were occluded, and on the sixth day after the second sitting, when the arteriovenous fistula was obliterated.

At autopsy nothing was found in the wound that could account for the fatal termination. The fistula had been completely sealed and all the sutures had held. The internal and external carotids were pervious and free from clot. The brain and thoracic organs were preserved for a separate and detailed examination in the laboratory. Marked evidences of chronic endarteritis and miliary aneurisms were discovered in the cerebral vessels, but the cause of the fatal termination was found in the heart. The aorta was dilated and showed atheromatous plaques. The left coronary was obstructed by thrombus and the right ventricle was distended with clot which extended into the pulmonary artery. The heart itself was of large size, dilated, showing evidence of myocardial degeneration.

I have dwelt with some detail upon the report of this patient's case because it presents many unusual, if not unique, features:

It is the first case that I have been able to discover in the literature in which the special technic of transvenous endo-aneurismorrhaphy has been applied to suppress an arteriovenous fistula of the jugulocarotid vessels with technical success. The only other instances that I can find, in which the *transvenous* method of endo-aneurismal suture has been applied, are reported six years later, and are: (1) The operation performed on a young soldier by René Le Fort, of Lille, on July 20, 1917 (*Bull. Acad. de Méd.*, Paris, No. 31, August 7, 1917), in which the *internal* carotid and jugular veins were involved. The fistulous communication was closed by suture, applied through an incision made in the pouch formed by the dilated internal jugular. The artery remained pervious, and the vein was obliterated by plication and mattress sutures (" capitonnage "), as in my case. The wound had been inflicted four months previously, and the technic was remarkable for its simplicity and rapid recovery of the patient.

The operation reported by C. P. Lecène, of Paris (*Bull. et mém. soc. de*

Chir. de Par., January 15, 1918, xliv, No. 1, 27–30), was performed on November 15, 1917. The patient, a soldier, aged twenty-five years, was wounded in the neck by a fragment of shell which perforated the common carotid and jugular, causing an arteriovenous anastomosis. The operation was performed about one month after the injury. In this case and in Le Fort's, the jugular vein was enormously dilated on a level with the arterial communication. The operator was able to close the slit-like opening of the fistula, which was clearly visible inside of the vein, by an intravenous suture with fine silk, and, in this way, he did a perfect restorative endo-aneurismorrhaphy, which allowed the common carotid to remain pervious. The vein itself was closed by intravenous sutures applied above and below the seat of the anastomosis. The result was a brilliant success, by which the carotid circulation was restored, though the vein was obliterated at the seat of the anastomosis.

This case, as the preceding of Le Fort, is noteworthy in many ways, and especially as illustrating the relative facility with which the cure of an aneurismal varix was effected in a particularly dangerous and difficult region. It is also a valuable tribute to the efficiency of the method, coming, as it does, from an operator who had previously entertained, and expressed, a decided prejudice against the endo-aneurismal methods of suture, but who, after this experience, loyally and honestly admitted that he had erred in his preconceived objections.

" *Mais l'expérience qui seule juge en dernier ressort, m'a montré que mes prevéntions contre cette intervention [l'opération de Matas] étaient tout a fait injustifiées.*"

In my patient the continuity of the collateral arterial current to the brain through the external and internal carotids by way of the bifurcation remained undisturbed, and is also one of the unique features of this case. The proof that this collateral circuit remained active was demonstrated after the common carotid and internal jugular had been occluded.

The chief indication for the operation was also unusual, and perhaps unique, in the fact that it was undertaken chiefly with the hope that the closure of the arteriovenous fistula would relieve the strain on the right heart due to the short-circuiting of the carotid stream into the venous system, causing a progressive dilatation with dangerous and distressing symptoms.

VII. The opportunity to test the full value and end-results of the transvenous route in attacking aneurismal varices, which was denied us in the preceding case, soon presented itself in a succession of aneurismal varices of the lower extremities, which came under treatment in our clinics in the interval between 1912 and 1919. The following two cases, abstracted from our records, suffice to show some of the peculiarities of the technic which has varied according to the conditions found in each case, but has always been guided by the same principle.

Traumatic Arteriovenous Aneurism (Aneurismal Varix) Involving the Femoral Vessels at the Groin, of Three Years' Standing, in which

*the Arteriovenous Communication was Successfully Closed by Trans-
venous Endo-aneurismorrhaphy, with Preservation of the Lumina of
Both Vessels.*—The patient, J. H. H., aged nineteen years, of West-
minster, S. C., shot himself accidently with a parlor rifle, 22-calibre
bullet. The bullet entered the abdominal wall about one and a half
inches below Poupart's ligament and ranged downward, striking
the femoral vessels at the groin, and losing itself in the depths of
the left thigh. A tumor formed just below the middle of Poupart's
ligament where a characteristic thrill and purring noise developed
on the third day following the injury. He came under my observa-
tion on January 11, 1912, *three years after* the accident occurred. The
affected limb was larger than the right, and he had large varicosities
all along the saphenous tract from the thigh to the leg, with typical
pigmentation of the skin and a rebellious ulcer below the knee which
had resisted all previous treatment. The site of the abnormal
vascular communication was easily localized at a point just below
Poupart's ligament, a little to the inner side of the midline. At this
point, the pulsation, thrill and characteristic murmurs were heard
with greatest intensity. From this point the murmurs and thrill
were transmitted upward as far as the umbilicus and below as far as
the knee. The details of the operation which followed are well
shown in the accompanying diagrams and drawings (Figs. 15–22).
Iliac vessels were exposed by an extensive subperitoneal dissection,
great difficulty being experienced in controlling the external iliac
vein and its tributaries which had attained enormous proportions.
The iliac vessels were provisionally controlled above and below the
anastomosis (after Poupart's ligament had been divided) by elastic
ligatures and padded clamps. The common femoral veins formed
a large, well-defined sac of egg-like shape at the site of the fistula
and at its junction with the saphenous. After controlling all the
vessels, the aneurismal phenomena were all stilled and the vessels
collapsed. The sac, which was fully three and a half inches in
length and two inches in breadth, had developed between the artery
and the vein, but at the expense of the vein. The constriction or
neck which united the sac with the artery was fully one and one-
half inches in length. The sac was opened longitudinally on the
venous side, exposing the full length of the large orifice in the
artery. This was closed by a row of continued, vaselined silk sutures
introduced from the venous side, thus bringing the endothelial sur-
faces of the orifices in perfect apposition. After this, a cuff flap was
cut off at the expense of the venous wall, thus detaching the artery
completely from the vein. This flap was sutured over the cuff in the
manner shown in the diagram, leaving the artery thoroughly pro-
tected against leakage. The suture of the vein was easily accom-
plished, owing to the excess and laxity of the venous sac. After
this all the controlling elastic ligatures and clamps were removed,
allowing the blood stream to return at once through its normal
channel. All the sutures in the artery and vein held perfectly, in-
suring the complete success of the operation. The operation was

long and tedious, as was to be expected in such a chronic case, lasting nearly four hours. This was due chiefly to the innumerable and enormously dilated veins which had to be secured and ligated in the superficial planes before the main vessels could be reached (Figs. 15 and 18).

The most notable post-operative feature of the case was the extraordinary tachycardia that developed suddenly after the restoration of the circulation through its normal channels. This tachycardia, during which the pulse ranged from 170 to 190, continued until after the patient had recovered from the anæsthesia and lasted for three hours after the the patient was returned to his bed. At the end of this time the pulse suddenly became irregular and dropped in three minutes to 110, where it continued until it became normal the next day. Apart from this remarkable incident the patient made an excellent recovery and was discharged completely healed and well on February 19, 1912. Three years after his return home his physician wrote me that the boy had been in perfect health and that he had grown to be a big and robust man.

In this case, as in all others of long standing, the baneful effects of the short-circuiting of the large arterial channels, especially at the root of the limbs into the venous circulation, were particularly noticeable, and proved that the sudden readjustment of the circulation by the closure of the abnormal arteriovenous communication is not without its dangers.

Arteriovenous Aneurism of the Femoral Vessels at the Apex of Scarpa's Triangle in a Boy of Fifteen Years in which the Orifice of Communication was Closed by a Transarterial Suture. A Pulsating Hæmatoma Caused by the Simultaneous Transfixion of the Artery and Puncture of the Vein by Stab (Fig. 23).—This boy, Julius B., was brought from Sterling City, Texas, September 3, 1916, twenty-four days after he had accidentally wounded himself in the right thigh with a long-bladed pocket knife while splitting a piece of wood. The knife had entered the upper thigh about five inches below Poupart's ligament. The boy was still suffering from the effects of severe hemorrhage. A linear scar indicated the point of entrance of the knife and about this was a spherical swelling which pulsated, purred and thrilled in the characteristic fashion of arteriovenous injuries. The pedal pulses were feeble, but on testing the collateral circulation by our methods, it was shown that an ample supply of blood was going to the periphery by the collaterals outside of the main channels, and that an obliterative operation could be performed with safety if it became necessary. Prophylactic hæmostasis was secured by the Esmarch bandage and the constrictor was held high up near the groin with a Wyeth pin. With the scar as the centre of the incision, a sac was opened above the sartorius which led to another cavity under this muscle. This cavity was already partially lined with a thin veil of organized exudates which hid the vessels completely. A slit-like opening about ½ inch in length was now discovered in the floor of this space running parallel with the long

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axis of the femoral vessels, which were lying superimposed one on the other under the thin lining of the sac. An exploration of this opening demonstrated that it led to the artery and not the vein, as we had at first supposed, and that this vessel had been transfixed and the vein punctured.

The flatness and breadth, as well as thinness of the collapsed artery, with the narrow slit-like wound lying in its centre, permitted us to suture and obliterate the arteriovenous opening simultaneously with the external wound in the artery. The technic adopted is shown in the accompanying Fig. 23. On removal of the constrictor, the blood rushed into the artery which pulsated, blood circulating on each side of the suture line and beyond, into the artery, distal to the central line of suture. All the aneurismal signs ceased completely and the circulation of the foot was perfect, the pedal pulses remaining as they had been before the operation. Healing took place *per primam*, and, after a short period of rest, hydrotherapy, and massage, the patient was discharged healed and well on the twentieth day after the operation. I have since heard from the patient, and up to the present time he is in perfect health.

This operation is unusual and perhaps unique in the fact that an arteriovenous fistula was obliterated through an abnormally thin arterial wall, thus constituting a trans-arterio-phleborrhaphy rather than the usual procedure of endo-phlebo-arteriorrhaphy.

IX. Our records show that four additional cases of arteriovenous aneurisms involving the femoral vessels have been operated upon in our clinics since going through the preceding experiences which exhibit individual features and peculiarities of special interest to the surgical technician which deserve detailed consideration in a separate publication. They all have the one feature in common, in that they were long standing aneurismal varices presenting all the difficulties and complications peculiar to the chronic stages of this class of lesions; each one offering a serious problem to tax the judgment, skill and resourcefulness of the most experienced operator. All of these, however, were happily solved by the intrasaccular methods herein described with such modifications as were suggested by the conditions met in the course of the operation. Finally, the experience gathered from these cases has convinced me that the possibilities of cure by this method are as great in arteriovenous aneurisms as in purely arterial.

X. Since writing these observations and in reviewing the history of the war, I am gratified to note that the aneurismal method of treating arteriovenous aneurisms by the intrasaccular suture of the communication orifice by the transvenous route, as described in this paper (" Matas-Bickham method ") has been received with favor by Sir George Makins in his excellent monograph on " The Gunshot Wounds of the Blood-vessels " (London and New York, 1919). In referring to the treatment of aneurismal varix, he says: " The indications for operation for this condition are less precise than in the case of the varicose aneurisms.

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There is no doubt that many aneurismal varices, especially in the upper extremity, do not call for operation, and may be left untouched without risk to the patient. Either pain, increasing local distention of the vein, or signs of increasing and troublesome obstruction to the peripheral venous circulation, may render operation advisable or necessary.

" The vessels may then be ligated above and below the level of communication and the varix excised. A far *preferable method is to close the communicating opening by suture,* as has already been described under the heading of arteriovenous aneurism. If a direct opening exists between the artery and vein, the latter should be opened freely; the communication is then exposed and may often be stitched up without any further preparation. If the sac be situated between the vessels, it should be opened first, and the communication can be stitched from this point."

Continuing on page 86, he again states: " In pure aneurismal varices the almost invariable route to the anastomotic opening should be through the vein; if this procedure be adopted the closure of the opening into the artery is easy and that of the incision into the vein simple in the extreme," etc.

Here, then, we have a full acceptance of the intrasaccular suture applied by the transvenous route which Bickham first described in 1904, as an application of the method of endo-aneurismorrhaphy to arteriovenous aneurisms which I had described in 1903. While it is gratifying that so experienced and eminent a surgeon as Sir George Makins should have so clearly signified his approval of this method, it is surprising that one so well informed in the literature of vascular surgery nowhere suggests or even hints in his book that this method had been devised, described, and applied in America ten years before the declaration of the war. In this he differs from his French colleagues, Lecène, Forgue, and others, who fully recognize the antebellum as well as the American origin of the method.

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STUDY OF ARTERIOVENOUS FISTULA WITH AN ANALYSIS OF 447 CASES

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The original paper, of which this article is a part, was published in volume xix of the Johns Hopkins Hospital Reports, and was written at the suggestion of Prof. William S. Halsted, who generously placed at my disposal all the material collected by him in the course of his study of arteriovenous fistula.

The earlier, more complete publication dealt specifically with each of the cases in the literature and recorded them in the form of a detailed and analytic chart and included, in addition, a complete bibliography for all instances mentioned in the text and charts.

Doctor Halsted's particular interest in this subject arose from his effort to determine the cause of the proximal dilatation of the artery, which has been observed in a number of these cases, and which he believes occurs invariably.

In his writings he has expressed the view that the dilatation of the artery which is (1) distal to the partially occluding band, (2) beyond the site of coarctation in cases of congenital stricture of the aortic isthmus, and (3) distal to the constriction of the subclavian artery by a cervical rib will be found to have the same cause as the dilatation of the artery central to an arteriovenous aneurism. The subject is discussed in his papers published in the *Journal of Experimental Medicine*,[1] *the Proceedings of the National Academy of Sciences*,[2] and in *Surgery, Gynecology, and Obstetrics*.[3]

Doctor Halsted's interest in the study was further stimulated by the conviction that an arteriovenous fistula may be responsible for the enlargement of the heart, which he has repeatedly observed as a complica-

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[1] Halsted, W. S.: An experimental study of circumscribed dilation of an artery immediately distal to a partially occluding band, and its bearing on the dilation of the subclavian artery observed in certain cases of cervical rib.

Reid, Mont R.: Partial occlusion of the aorta with the metallic band. Observations on blood-pressures and changes in the arterial walls. *Jour. Experimental Medicine*, 1916, xxiv, p. 271.

[2] Dilation of the great arteries distal to partially occluding bands. *Proc. of the Nat. Academy of Sciences*, 1918, iv, p. 204.

[3] Cylindrical dilatation of the common carotid artery following partial occlusion of the innominate and ligation of the subclavian. *Surgery, Gynæcology, and Obstetrics*, 1918, xxvii, p. 547.

tion in these cases, and which Dr. Mont Reid, at his suggestion, has attempted (and with success) to prove.

This study is carried to the year 1914, but, in addition, reviews all the cases recorded among the surgical histories of The Johns Hopkins Hospital, as well as a number of selected instances appearing in the surgical literature of the recent war.

I. HISTORY OF ARTERIOVENOUS ANEURISM

To William Hunter undoubtedly belongs the credit of first describing accurately not only the clinical features, but also the disturbed mechanism of the vascular physiology of arteriovenous fistula. This he did in 1757, and this analysis was followed in 1762 by the detailed publication of the two cases which formed the basis for his description and conclusions.

An excerpt from the account of his first case reads:

About fourteen years ago a lady was bled in the basilic vein of the arm by a surgeon who was unfortunate enough to wound the artery through the sides of the vein. He was instantly sensible of the misfortune by the violence of the stream that gushed from the vein. At the time of the accident, and for a great while afterwards, every method that could be suggested was taken for preventing or curing an aneurism by compression.

The veins in the bending of the arm, and especially the basilic, the vein that had been opened, were prodigiously enlarged at that place and came gradually to their natural size about two inches above and as much below the elbow. When emptied by pressure they filled again almost immediately; and this happened even when a ligature was applied tight about the forearm immediately below the affected part. Both when the ligature was made tight and when it was removed they shrunk and remained of a small size while the finger was kept tight upon the artery at the point where the vein had been opened in bleeding. There was a general swelling and fulness at the affected part and in the course of the artery, which seemed to be larger and to beat stronger than what is natural all the way down the arm. There was likewise a pulsation in the dilated veins corresponding to the pulse in the artery; and there was a hissing sound and a tremulous jarring motion in the veins, which was very remarkable at the part which had been punctured, and became insensible at some distance both upwards and downwards.

Though such a case has never before entered my thought, I was so well convinced by the symptoms of its arising from a communication between the artery and the vein that I gave an opinion to that purpose, and, therefore, advised her to do nothing while there should be no considerable alteration.

The following extract concerns Hunter's second case:

A male who was bled in the arm about five years previous to the examination.

The trunk of the brachial artery is considerably enlarged all the way down the arm, and its pulsation so strong that it is apparent to the sight. A little above the bend of the arm the artery makes a remarkable serpentine turn, which raised up the skin, and by the force of the pulsation looks as if it was a beginning aneurism. But notwithstanding the size and force of pulsation of the brachial artery be much more considerable than in the other arm, the artery at the wrist is much smaller and its pulsation much weaker. Whence it is evident the disorder

has brought on a great disproportion in size between the dilated trunk and the shrunk branches of the artery in the diseased arm.

At that place where the puncture was made, a bag rises up, projecting as much as if it were a large nutmeg under the skin. This bag is filled entirely with fluid blood, disappears under pressure, and has a strong pulsation. Its deepest part is manifestly united with the artery. Over the inside and the most prominent part of this bag the basilic vein runs, and is so firmly united to it and blended with it by communication that it is difficult to determine whether the bag be a sinuous dilation of the part of the vein or if it be an adventitious cavity between the artery and vein formed in the cellular membrane, though I am more inclined to believe the last. Its communication, however, both with the artery and vein, is undoubted, as will appear by what follows.

The basilic vein is very much enlarged, and its extension is very apparent and makes a considerable external swelling. But when the arm is held up so as to give the returning blood the advantage of running downwards, the vein subsides and no swelling whatever appears, except just at the punctured place, where the bag continues nearly as much dilated as when the arm hangs down.

There is a remarkable tremulous motion (as well as considerable pulsation), both in the bag and in the dilated vein, as if the blood was squirted into it through a small hole. It is like what is produced in the mouth by continuing the sound of the letter " R " in a whisper. It is the strongest at the very place where the vein was punctured, and becomes gradually less perceptible from that part upwards. It is even very apparent to the sight. It is entirely stopped by pressing the trunk of the artery anywhere above, or by pressing the bag or the vein at the punctured part, and there the very point of the finger is of sufficient breadth for the purpose. These compressions instantly stop the tremulous motion, and it instantly returns again when they cease. It is the same when the arm hangs down and when held up, and when loose and girded by a ligature below the punctured part.

This motion is not only felt and seen distinctly, but heard if the ear be held near the part; and if the ear touches the skin the sound is much more loud and distinct. It is a hissing noise, as if there was a blast of air through a small hole and interrupted, answering precisely and constantly to the stroke of the heart or the diastole of the artery. It stops immediately when the trunk of the artery is compressed and returns instantly when the artery is free. The patient is so sensible of the noise that he often finds that it keeps him from falling to sleep when the arm happens to be near his head, and then commonly puts it down by his side in bed that he may go to rest.

If one looks with attention while the compression is taken from the artery, you can trace the blood rushing first down the artery, then across the bag, and last of all, flying upwards in the vein.

Guattini, an Italian, who in 1785 published an accurate description of this type of aneurism, was by Scarpa given joint credit with Hunter for the discovery. Eighteen years, however, had elapsed between Hunter's report and that of Guattini. Moreover, in that interval Cleghorn, White and Armiger had each published detailed descriptions of arteriovenous aneurisms of the brachial vessels.

To Sennert, too, different authors have unfairly attributed the credit of this discovery, but he, as did other foregoing observers, misconstrued undoubted cases of arteriovenous fistula as cases of simple arterial aneurism.

It is interesting to note that this discovery did not take place until the middle of the eighteenth century, after the lancet mode of venesection

had been in vogue for years. Since it had been practiced in many instances by men little versed in the arts of anatomy and surgery, it follows fairly logically that simultaneous wounds of the artery and vein were fairly common long before the discovery was made. If the phenomena consequent upon the union of artery and vein were present, they were mistaken for evidences of arterial aneurism.

New observations followed at an early date, but Delacombe, in France, published the first case of arteriovenous aneurism in which the clinical findings were confirmed by the lesions found at autopsy.

The later theses of Morvan, Goupil, Henry, and others, together with a monograph by Delbet and a paper by Bramann, have done much to clear up the various phases of the clinical and pathological pictures.

II. CLASSIFICATION

Definition of Arteriovenous Aneurism.—By arteriovenous aneurism is meant any pathological union between an arterial and a venous channel, whether that communication exists between a systemic artery and vein, between an artery and a venous sinus, or between the aorta and the right ventricle, the right auricle, or the pulmonary artery. These communications fall naturally into different varieties according to certain definite changes in form and structure obtaining in the various parts of this complex.

Aneurismal Varix.—The simplest form of such communication is that in which no saccular dilatation, true or false, springs from the artery, vein, or channel of communication (Fig. 1). This variety was called by Broca *phlebartérie simple,* but in the general, more confusing nomenclature, bears Cleghorn's designation *aneurismal varix.* Here the wounds of the artery and vein are approximated and become agglutinated with a single orifice of communication. In addition, there is a gradual dilation of the vein. This tumor is *aneurismal,* having communication with the arterial circulation, and because of its venous dilatation is designated as *varix.*

The anatomic factors governing the formation of this type of aneurism are: The proximity of the involved vessels, the space afforded them in the vascular cleft, and the amount of support given them by the surrounding tissue (Makins).

Varicose Aneurism by Dilatation.—When the vein increases in size and bellies out into a circumscribed swelling, and when that dilatation involves only the walls of the expanded vein, the resulting aneurism was called by Broca *varicose aneurism by dilatation.* It seems arbitrary, however, to distinguish between this type and that which constitutes aneurismal varix, for one may readily pass from the one into the other by the most insensible gradations.

Encysted Varicose Aneurism.—In another group of cases, the details of the injury are such that either artery or vein, or both artery and vein,

are transpierced, affording channels for arterial or venous extravasations into the tissues. Although the edges of the arterial and venous wounds destined to form the fistulous communication may early become approximated, the other vascular wound or wounds may remain patulous. In this instance a false aneurismal cyst or cysts, with walls formed from perivascular tissue and laminated clot, will occur at the unhealed sites of injury, and it is the connection of these false circumscribed sacs which furnishes the basis for subdivisions of this variety. When the cyst of new formation surmounts the vein, the *encysted varicose aneurism* is designated as *venous* (Fig. 3) ; but when this sac rests singly on the artery, the aneurism is known as *arterial encysted varicose aneurism* (Fig. 2). When false aneurismal cysts are noted upon both the artery and the vein, the resulting rare aneurism is termed *double arterial and venous encysted varicose aneurism* (Figs. 4 and 5).

Intermediate Encysted Varicose Aneurism.—In a certain group of cases where a profuse extravasation of blood has occurred at the point of injury, so situated as to separate the artery and vein and to prevent their adhesion and union, and forming a false aneurismal sac which serves as a channel of communication, the tumor is known as an *intermediate encysted varicose aneurism* (Figs. 6 and 7).

Were the above condition to appear combined with superimposed false sac on either the artery or the vein, the complex is known as *double arterial or venous and intermediate encysted varicose aneurism* (Fig. 8).

To Cruveilhier, in 1853, we are indebted for the essential features of the above classification.

Arteriovenous Aneurism.—A very rare type of aneurism in which an artery has a fistulous communication with two veins may be designated as an *arteriobivenous aneurism.* Such anatomic relations existed in Park's brachial and Mignon's axillary fistula (Fig. 9).

Chauveau reported an arteriovenous aneurism of a most curious variety, occurring on the jaw of a horse embracing the muscular maxillary artery and vein. From this thin and dilated artery, there arose five or six large flexuous branches, ampulliform at their origins, making large mutually anastomosing ramifications on the walls of the venous sac. Definite communication existed between these arterial anastomoses and the dilated vasa vasorum in the wall of the varicose vein, and these again communicated directly with the main channel of the vein. This complex Chauveau describes as an *arteriovenous aneurism by dilatation of the vasa vasorum of a varicose vein* (Fig. 10).

III. ETIOLOGY

The predominating cause of arteriovenous aneurism is some form of traumatism. The detailed table of causes given below will show that in a total of 447 cases 383, or 85.7 per cent., resulted from injury.
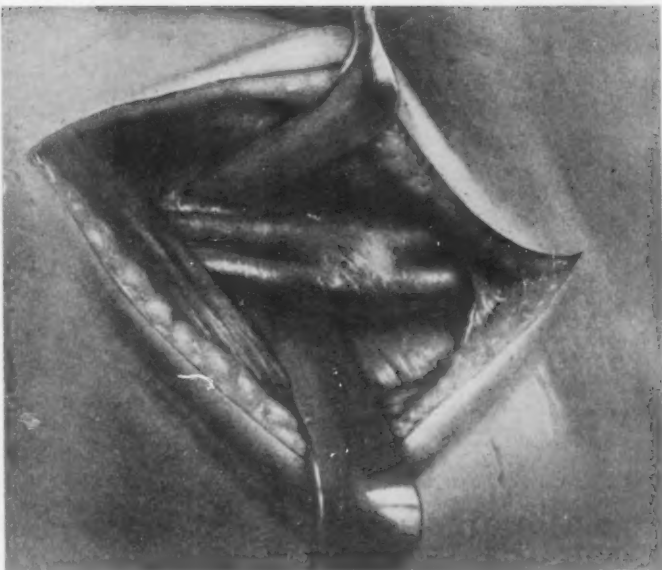
FIG. 1.—Aneurismal varix of the femoral artery and vein. Horsley:
Med. and Surg., 1917, i, 25–29.

FIG. 2.—Arterial encysted varicose aneurism of the femoral vessels.
Guinard: Bull. et mém. Soc. de Chir., n. s., 1902, xxviii, 1125.
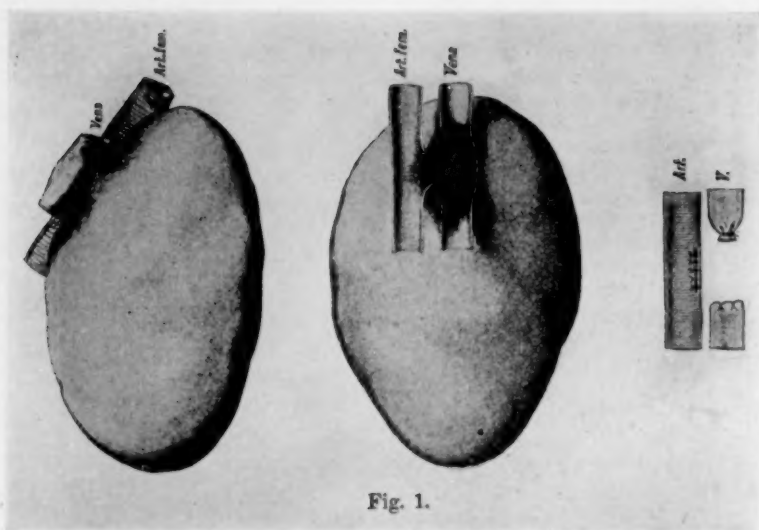
Fig. 1.

FIG. 3.—Venous encysted varicose aneurism of the femoral vessels. Garrè: Deutsche Ztschr. f. Chir., 1906, lxxxii, 287.

FIG. 4.—Double arterial and venous encysted varicose aneurism of the femoral vessels. Eisenbrey: J. Am. Med. Assn., 1913, lxi, 2155.
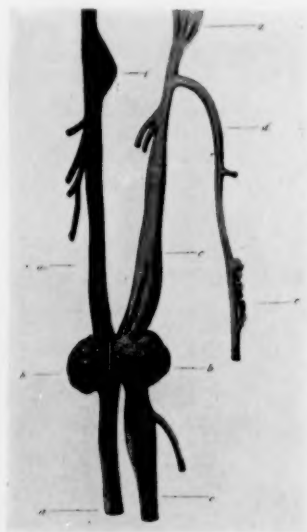
FIG. 5.—Double arterial and venous encysted varicose aneurism of the femoral vessels. Gallerand: Arch. de méd., nav. 1882, xxxviii, 146.
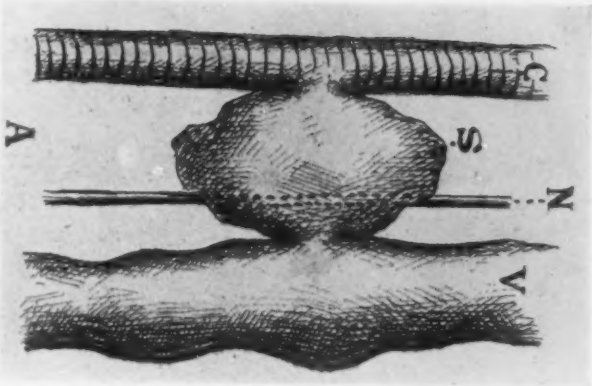
Fig. 6.—Intermediate encysted varicose aneurism of the common carotid artery and internal jugular vein. Cranwell: Rev. de Chir., xxxiv, 1906, 826.

Fig. 7.—Intermediate encysted varicose aneurism of the femoral vessels. MacCallum's: Textbook of Pathology.
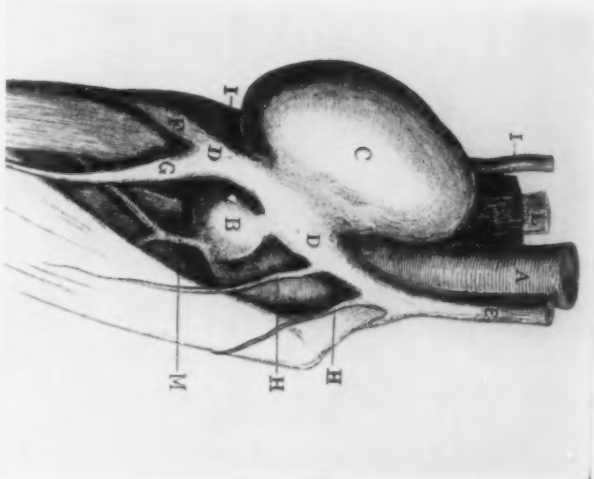
Fig. 8.—Double venous and intermediate encysted varicose aneurism of the brachial vessels. Broca: Bull. de la Soc. de Chir., 2 d. s., 1863, iv, 392.
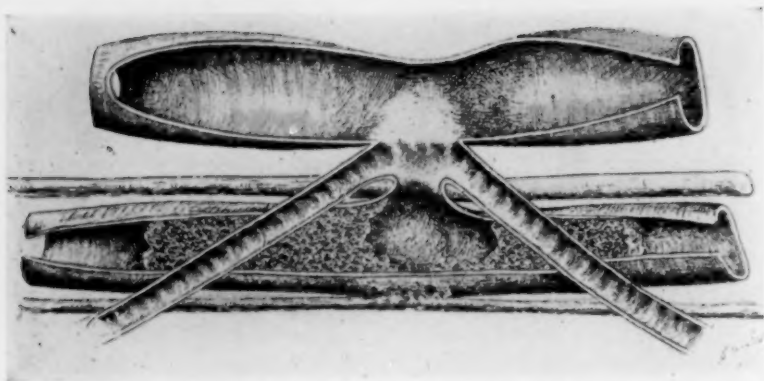
FIG. 9.—Arterio-bi-venous aneurism of the axillary vessels. Mignon: Bull. et mém. de Soc. de Chir., n. s., 1905, xxxi, 535.
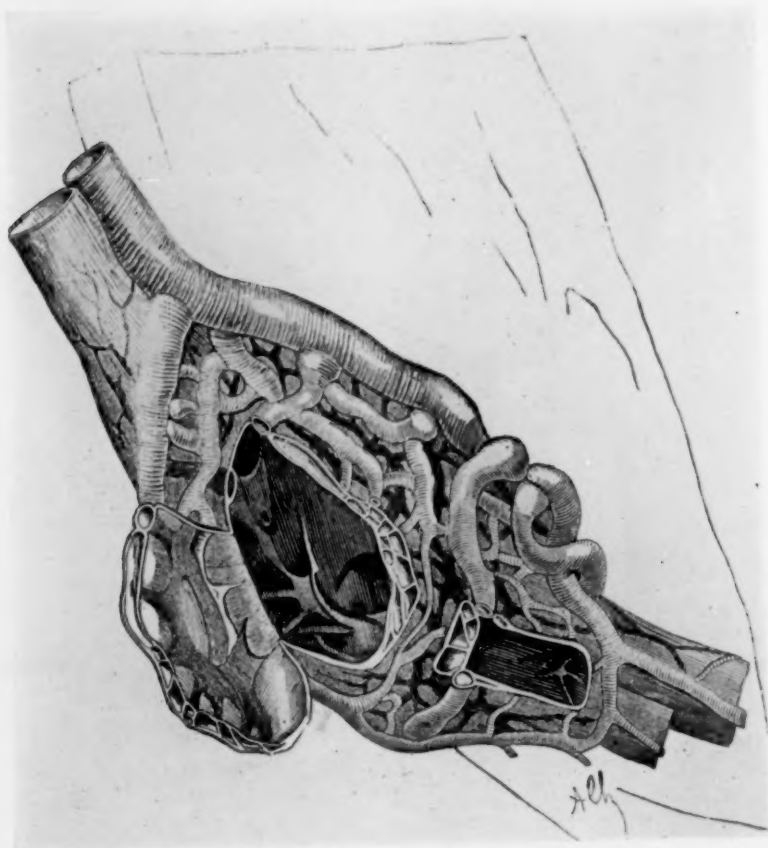
FIG. 10.—Arteriovenous aneurism of vasa vasorum of varicose vein. Chauveau: Jour. de la physiologie de l'homme, 1860, iii, 685–694.
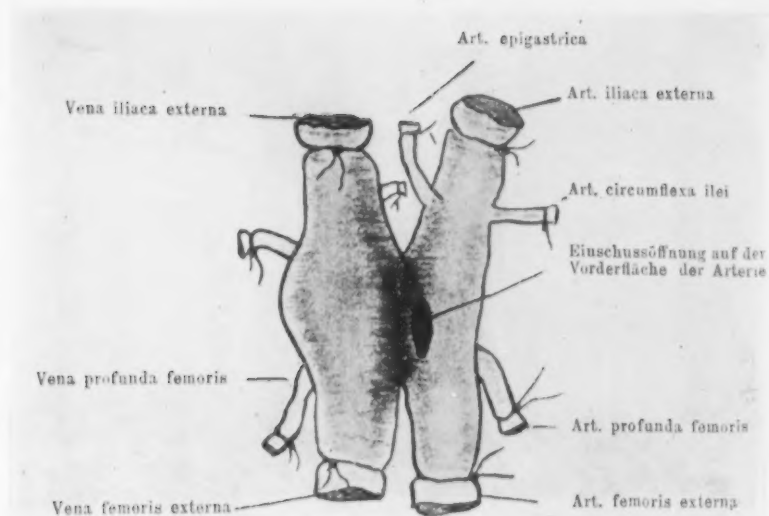
Fig. 11.—Extirpation of aneurism in aneurismal varix of the femoral vessels.   Thiel:
Centr. f. Chir., 1859, xxvi, 1226.
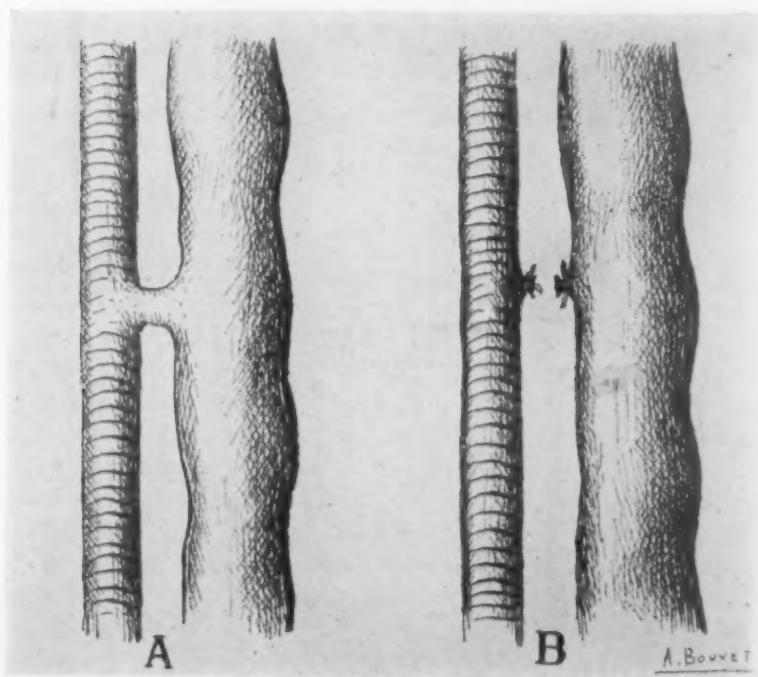
Fig. 12.—Ligation of the communication in aneurismal varix of the popliteal vessels.
Cranwell: Rev. de Chir., 1906, xxxiv, 824.

FIG. 13.—Lateral suture and reinforcement of artery and end-to-end suture of vein in aneurismal varix of the femoral vessels. A, artery; B, vein; C, communication between artery and vein; D, hole in artery after dissecting out communication, the dilated portion edges; E, the two ends of the veins ready for end-to-end anastomosis, the dilated portion having been cut away in order to get healthy vein tissue for anastomosis; F, artery sutured laterally with fine silk sutures; G, vein sutured end-to-end anastomosis; H, graft from internal saphenous vein surrounding the sutured artery, and sutured on opposite side to sutured artery at I. Godwin: Brit. Med. J., 1915. ii. 925.

FIG. 14.—Lateral reinforced suture of the artery, with resection and end-to-end suture of the vein in popliteal varix. Da Costa: ANN. SURG. 1912, iv, 593.

Of the main traumatic factors, wounds from projectiles and knives played about an equal rôle, 189 cases resulting from the former and 161 cases from the latter.

Bullet Wounds.—The bullet was the causative factor in 166 instances, and its more extended use in modern warfare has made arteriovenous aneurism as familiar now as it formerly was from promiscuous venesection.

In the earlier wars the occurrence of arteriovenous aneurism from bullet wounds was rare, for among 400 vascular injuries in the service of Demme in the North Italian Military Hospital in 1859 not a single case of arteriovenous aneurism was reported; nor were any noted in the Crimean War. Only 8 cases were reported from the Franco-Prussian War in 1870–1871. In this regard Küttner remarked that aneurisms were usually associated with injuries of large arteries, and their occurrence was infrequent in those wars because of the larger wounds and the frequent hemorrhages. In modern warfare, however, conditions are exactly the opposite and aneurisms constitute a very interesting class of war wounds.

According to von Bergmann, arteriovenous aneurism results from the clean, narrow puncture so liable to occur with the rapidly formed, penetrating wounds caused by the small calibre bullet. The conditions associated with the formation of traumatic arterial aneurisms are identically those required for the production of the arteriovenous variety, namely: a small orifice of entrance and exit for the bullet, a narrow but long curved channel usually crossing the course of the vessels in an oblique direction, a small perforation in the artery, followed by rapid closure of the wound and primary union of the bullet's track.

Such conditions prevailed during the more recent and the late wars.

In the official report from the surgical cases noted in the South African War, 1899–1902, Surgeon General Stevenson, of England, reported 63 cases of traumatic aneurism, of which 33, or almost 50 per cent., were of the arteriovenous variety. Saigo, writing on traumatic aneurisms in the Russian-Japanese War, found approximately the same proportion.

A variety of *bomb, shrapnel, and grenade wounds* account for 23 additional cases. It is interesting to note the increasing frequency of arteriovenous aneurisms caused by explosives since Bremann, in 1886, gave his excellent analysis of 159 cases in which only 29, or 18.2 per cent., resulted from this general source. In our series of 447 cases, 189 were caused by injury from projectiles, making a total of 42.2 per cent. The incidence of arteriovenous aneurism in the later decades is noticeably greater.

Cut and Stab Wounds.—Cut and stab wounds, including injuries by lancet, knife, stake, chisel, bayonet, and spike, are responsible for 161 aneurisms, or 36 per cent.

Arteriovenous aneurism resulting from venesection has in recent years become of comparatively rare occurrence, for indiscriminate and inefficient bleeding has ceased to be a practice of modern medicine, and the unintended consequences of the measures have therefore ceased to be frequent. Among Bramann's collection of 159 cases 56, or 35.2 per cent., resulted from venesection. In Delbet's series of 250 aneurisms, 92 cases, or 36.8 per cent., resulted from this source. In 447 cases in this series only 38, or 8.5 per cent., followed venesection.

Contusion.—The nine cases falling under the heading of contusion are made up indiscriminately of injuries no more specific than blow, fall, trauma, injury, and wound, and include an aneurism reported by Robinson in an amputation stump of the knee.

According to Matas, the aneurismal varices occurring in amputation stumps are usually associated with massive ligatures of both vessels followed by infection.

Fracture.—Fracture was the traumatizing agent in the injury of the vessels in the following five cases: Cushing's aneurism of the internal carotid artery and the internal jugular vein from a fracture of the skull; Gross and Sencert's fistula of the anterior tibial vessels from a fracture of the leg; Reboul's subclavian aneurism from a fracture of the clavicle; Findlay's femoral aneurism from a fracture of the femur; and Bornhaupt's aneurism of the brachial vessels from a fracture of the humerus.

Secondary Aneurism.—There is a group of twenty secondary arteriovenous aneurisms which followed the erosion into neighboring venous channels of preëxisting arterial aneurisms of the ascending and the abdominal aorta.

Congenital.—In three cases the fistulæ were present from birth. Sir Prescott Hewett reports an arteriovenous aneurism of the common iliac vessels in a hydrocephalic in whom the right thigh at birth was larger than the left, and the superficial veins of which were engorged. In

Busche's temporal fistula a pulsating tumor the size of an egg had existed since birth. In Halsted's aneurism about the external carotid artery a buzzing and throbbing in the right side of the neck was noticed when the patient was three days old.

IV. PATHOLOGY AND PATHOLOGICAL PHYSIOLOGY

Venous Dilatation.—An ever-increasing dilatation of the vein about the fistulous communication is one of the most constant features of arteriovenous aneurism. This dilatation may be more or less uniform and may extend over a considerable portion of the whole vein, or may be at its maximum at the point of communication. The fundamental cause of these venous changes is the increased pressure in the veins produced by the passage in them of arterial blood.

Normally, the pressure of the blood in the veins is slight, and the venous blood in them is carried by the *vis a tergo* communicated through the capillaries, aided by such other influences as the pressure of the contracting muscles, the changing position of the limbs, and the suction exerted by the thorax during the inspiration. The numerous valves placed along their course preserve each advance as it is made, and protect the underlying vessels from the extension to them of any accidental increase in the trunk above.

When arterial blood passes directly from an artery into its corresponding vein, it does so under a pressure which far exceeds the normal blood-pressure in that vein, and, since it cannot escape toward the heart without lifting and rapidly pushing before it the venous column on the proximal side, the increased pressure must be exerted on the lateral wall of the vein. Under such increased pressure the wall of the vein yields and its lumen enlarges. So long as the calibre of the vein increases and the vein valves distal to the communication remain sufficient, this added arterial pressure is not transmitted directly into the column of blood in the peripheral vein, but merely obstructs its central passage to the heart by imposing an obstacle against it. When, however, the valves yield under pressure, or become insufficient from the enlargement of the vein, and the arterial pressure is transmitted against those segments thus deprived of protection, the same changes in turn occur in them and a consequent dilatation of the vein ensues.

Pressure conditions peculiar to the internal jugular vein and other large veins of the neck account for a marked abnormality in that region. Stimson was the first to note that in the internal jugular vein the blood, instead of being pushed by the *vis a tergo,* is being pulled or drawn along by the *vis a fronte,* the strong suction of the chest at each inspiration, and the feebler one of the elastic return of the lung upon itself during inspiration. Instead of being distended, the wall of the vein is habitually flaccid, and the pressure in it is low or even negative. In addition, its

lumen is very large and it communicates within a very short distance with other trunks whose lumina are as large as its own, in which also the pressure is negative and into which, therefore, any excess of blood will readily escape. In other words, if there is an aneurismal dilatation or sac it is not large and has no tendency to grow larger. The average internal pressure is low because the incoming blood is no longer confined, but escapes into the vein as readily as it enters from the artery, and is thus prevented from exerting a distending influence on the wall of the dilatation or sac. The change, once established, has no tendency to increase. Stimson's postulate finds ample verification and corroboration in the study of the aneurisms of the common carotid artery and the internal jugular vein occurring in this series.

When, on the other hand, the external jugular vein is involved, and where conditions more nearly resemble those found in the other parts of the body, and where the venous escape to the heart is less free, there is a resulting dilatation of the vein.

The extent and location of the dilatation of the vein are dependent upon several well-recognized factors: First, the size of the communication determines the amount of arterial blood diverted through the fistula exerting pressure on the vein; second, the resistance afforded by the varying denseness of the perivascular tissue; third, the duration of the fistula; fourth, the degree of patency of the central segment of the vein; and fifth, the influence of gravity.

Venous Hypertrophy.—Although occasional large sacculations may be met with, as a rule, the veins support their increased vascular tension to an unexpected degree, owing to the acquired hypertrophy of the muscular coat. This ability of the vein to hypertrophy and to assume the work of an artery is shown in no more conclusive manner than by the admirable experiments of Alexis Carrel, who has demonstrated the feasibility of transplanting a segment of vein into an arterial defect several centimetres long by means of a double end-to-end suture. "Aided by the support of the surrounding tissues and by its own hypertrophy, the interposed segment of the vein, after a temporary slight ballooning, soon effectively plays the part of the thick-walled artery for which it has been substituted." The changed appearance of the vein, due to the hypertrophy of its muscular coat, has been termed *arterialization*.

There has been considerable controversy over the reason for these changes, Breschet alone contending against an explanation on purely mechanical grounds, and considering them the result of chemical changes in their walls wrought by the influx of arterial blood.

Pathological Changes in Vein Valves.—The vein valves, since they play a most important mechanical rôle in protecting the distal venous column from abuse, show important changes. As the lumen of the vein increases and the head pressure from the artery continues, the burden of the valve becomes increasingly heavy, until pair by pair they become insufficient.

In Socin's femoral fistula of nineteen days' duration, the first set of valves distal to the communication were almost destroyed, whereas the set next below were intact, while with fistulæ acting over a longer duration the valves at a greater peripheral distance fail to function. In Bramann's axillary aneurism of one and one-half years' duration, the valves, as far distally as the opening of the median basilic vein, were insufficient, and an examination of one of them located at some distance from the fistula showed one segment much shrunken, forming a ridge in the lumen of the vessel, with the other torn and lying adhesed to the side of the vein.

Rokitansky pointed out that valvular hypertrophy took place below that point in the distal segment of the vein where a moderately increased but continuous arterial pressure was maintained. This feature is illustrated in Rokitansky's own axillary aneurism and Robert's femoral aneurism.

According to Matas, the resistance of the valves favors the dilatation of the vein in segments, forming tumors which vary from the size of a pea to that of a large egg, or even to a fœtal head.

Changes in the Internal Saphenous Vein.—It is important here to make certain observations relative to anatomic characteristics peculiar to the internal saphenous vein, such as the extraordinarily strong valves at its mouth, and an absence of anastomosis with the deeper veins. J. Gay and W. Braune have demonstrated that but one small anastomosis exists between this long saphenous and the deep veins of the thigh. Because of these findings, there are here remarkably few instances of the pathological changes found elsewhere. In three cases of femoral aneurisms only—those of Pemberton, Gallerand, and Davies-Colley—did dilatation and hypertrophy occur.

Bone and Calcium Deposits about the Fistula.—At various stages in aneurism formation, unusual bone and calcium deposits have been noted on the walls of the sac in the immediate vicinity of the fistula. Zoege von Manteuffel reported an ossified varicose aneurism of the femoral vessels of only four weeks' duration, which communicated directly with the marrow cavity of the femur. Gallerand's femoral aneurism was found to be hard and cornified throughout, and intimately attached to the femur; it contained numerous phleboliths which the author asserted were mere fibrinous clots which had undergone calcium metamorphosis. The sac wall of Trélat's popliteal aneurism was semi-flexible, thick, and resistant, and as difficult to cut as a piece of leather, while its internal surface was studded with calcified and atheromatous plaques. In Beaumont's aneurism of the femoral vessels a small deposit of calcareous material was noted in the laminated fibrin suspended in the sac. Intramural calcium deposits were seen in the femoral aneurisms of Perry, von Wahl, and Eisenbrey.

Organized laminated clot within the aneurism, though rarely seen, has been reported in the cases of Beaumont and Eisenbrey.

Proximal Dilatation of the Artery.—Hunter, in 1762, recognized the

dilatation of the artery proximal to the fistula in his two cases and attributed it to the lessened work which the artery was called upon to perform.

According to Hodgson, " The enlargement of the artery above the tumor appears to be the effect of that property by which the size of arteries becomes adapted to that of the parts which they supply. The stream of blood, which at each pulsation of the heart passes through the wound into the vein, is so much taken from the supply intended for the nourishment of the limb. To compensate for the stream which passes through the wound in its coat, the main artery enlarges in the same manner as an artery becomes dilatated to supply a praeternatural growth."

Broca concluded that the lessened arterial pressure, which resulted from the deviation of blood through the fistula, called to the part a larger quantity of arterial blood, and he subscribed to the physiological teaching that the calibre of the vessel, other things being equal, places itself in harmony with the amount of blood which traverses it.

According to Bourges, the proximal artery loses its tone and resistance as a result of vasomotor change, while the thinning of its walls is a result of malnutrition due to some inherent change in the blood caused by the diminished pressure, on the basis that functional inertia may result in nutritive alterations.

The dilatation and thinning of the artery, according to Delbet, are to be explained on the basis of disuse atrophy, since the artery in the presence of the fistula needs no longer to contract against the customary arterial pressure.

Breschet explains the phenomena on the assumption that venous blood traverses the fistula and enters the artery during the period of cardiac diastole. Without placing any reliance on this hypothesis, it is well to note Franz's experimentally produced fistulæ on dogs in which he ascertained that occasionally the venous pressure about the fistula may exceed that of the arterial.

It has been stated by some that the central dilatation of the artery varies directly in size with the duration of the fistula. In Gripat's brachial aneurism, with a duration of forty-two years, the subclavian artery had attained the volume of the abdominal aorta; there are, however, numerous instances of long duration in which the artery is little or not at all enlarged.

Delbet attaches some importance to the age of the patient, noting that in the cases of Adelman, Selenkow, Perry, Rokitansky, and Broca, the patients were more than forty years old.

What has been said concerning this fairly constant phenomenon, the proximal dilatation of the artery, perhaps justifies the collection of detailed descriptions of this feature, listed according to author and location. In the 447 cases in this series this characteristic was noted in 57 instances, giving a percentage total of 12.7.

TABLE OF PROXIMAL DILATIONS

Author and Case No.	Location of fistula	Duration of fistula and description of proximal dilation
Rokitansky (85)......	Axillary	Duration of fistula, 33 years. Proximal dilation of axillary artery.
Osler (100)..........	Axillary	Duration of fistula, 30 years. Proximal dilation of axillary artery in region between the thoraco-acromial and internal mammary arteries.
Hunter (140)........	Brachial	Duration of fistula, 5 years. Marked proximal dilation of brachial artery with visible pulsation. Above bend of arm the artery makes remarkable serpentine turn which raises up the skin and resembles a beginning aneurism. Artery at wrist much smaller than that on opposite side.
Cleghorn (141).......	Brachial	Duration of fistula, a few weeks. Humeral artery seems considerably enlarged, and pulsation is visible from axilla to elbow.
White (142).........	Brachial	Duration of fistula, 10 years. Brachial artery much enlarged proximally.
Adelmann (147)......	Brachial	Proximal dilation of brachial artery.
Roux. Obs. 1 (156)...	Brachial	Duration of fistula, 6 years. Brachial artery above elbow attained considerable size, and its walls greatly thinned. Over whole artery in upper arm to axilla, the artery was almost size of middle finger, with almost aneurismal dilation. Size of arteries not sensibly larger than normal.
Roux. Obs. 2 (157)...	Brachial	Duration of fistula, 18 months. Proximal dilation of brachial artery.
Broca (167)..........	Brachial	Duration of fistula, 16 years. During last few years artery dilated to extraordinary degree. New aneurism, distinct from that on elbow, developed on brachial artery on middle of arm. Axillary and brachial arteries so dilated could not be compressed. Dilation of arterial system reached to innominate artery, because right common carotid artery was much more voluminous than left. Axillary artery larger than aorta and walls very much thinned. An arterial fusiform aneurism size of hen's egg was at point of amputation.
Gripat (178).........	Brachial	Duration of fistula, 45 years. Strong pulsations of subclavian artery, which appears size of normal aorta. Collapsed brachial artery measures 13 mm. above sac, where it is very atheromatous, and 8 mm. below, where it is flexible.
Warren (205)........	Hand	Arteries size of the carotids and so dilated as to form what might be called sinuses.
Seger (225)..........	Femoral	Proximal dilation of femoral artery.
Perry (226)..........	Femoral	Duration of fistula, 4 years. External iliac arteries, especially the left, were extremely tortuous, being reflected upon themselves in a singular manner, during their course towards their crural arch, a condition which had, no doubt, given rise to impression of artery being very dilated, since it conveyed to hand simultaneously the combined pulsations of the folded portions. Coats of femoral artery were no thicker than those of a vein, the attenuation having taken place equally in all its coats.

TABLE OF PROXIMAL DILATIONS—*Continued*

Author and Case No.	Location of fistula	Duration of fistula and description of proximal dilation
Horner (228).........	Femoral	Duration of fistula, 4 months. Artery had appearance of a dilation.
Baker (229)..........	Femoral	Duration of fistula, 5 years. Profunda artery greatly dilated distal to fistula. Femoral artery normal.
Pemberton (236).....	Femoral	Right external iliac artery dilated, twisted and tortuous.
Cordonnier. Obs. 2 (238)	Femoral	Duration of fistula, 23 years. Artery slightly flexous above aneurism; below its calibre was normal.
Cordonnier. Obs. 3 (239)	Femoral	Duration of fistula, 15½ years. Proximally one feels the femoral artery much larger than on the opposite side. Moreover it is flexous and forms a sort of italic "S".
Beaumont (241)......	Femoral	Duration of fistula, 11 years. On proximal side of aneurism, superficial femoral artery was greatly dilated, admitting two index fingers; on distal side, it was much contracted. Common femoral and external iliac arteries on their whole course were equally dilated, but somewhat thinned and otherwise healthy. External iliac arteries also greatly lengthened and thrown into a large curve.
Brindejonc-Tréglode.. (242)	Femoral	Above tumor femoral artery seems to be very large but healthy. Below, calibre is much smaller than in other leg.
Hulke (248).........	Femoral	Duration of fistula, 3 years. Femoral artery dilated proximally.
O'Grady (254).......	Femoral	Duration of fistula, 15 years. At operation femoral artery found to be as large as man's middle finger, and the coats thin and unhealthy. External iliac artery resembles abdominal aorta in size. Distended and tortuous, it resembled a sausage in size, with the appearance of a coil of small intestine.
Banks (262).........	Femoral	Duration of fistula, 6 years. Artery above point of communication somewhat enlarged, and as it neared venous opening, increased in size and slightly sacculated, having a blind pocket which would hold a pea.
Gallerand (263)......	Femoral	Duration of fistula, 22 years. Little below crural arcade on internal surface, is a well-marked dilation, about as large as a cherry, which constitutes a veritable aneurism by dilation. Below tumor popliteal artery is diminished in calibre, and has undergone a sort of "des artérialization." Femoral artery just above fistula was not enlarged.
Schwartz (267).......	Femoral	Duration of fistula, 9½ months. Examination of artery above tumor shows that artery is beginning to dilate.
Davies-Colley (271)..	Femoral	Duration of fistula, 5 years. Diameter of artery at upper end of wound was about ⅝ inch. Opposite to middle of incision it widened to almost an inch, and from being cylindrical above, it was here marked by a shallow longitudinal groove as if it were about to divide, but lower still became again cylindrical, and diameter was reduced to ½, or a little more. In size and color resembled a congested piece of small intestine.

TABLE OF PROXIMAL DILATIONS—*Continued*

Author and Case No.	Location of fistula	Duration of fistula and description of proximal dilation
Decamps (272).......	Femoral	Duration of fistula, 16 years. Femoral artery, thinned, is dilated to site of collateral on which sac is found. Below the calibre is slightly diminished.
Roberts (282)........	Femoral	Duration of fistula, 6 years. Femoral artery hypertrophied with small sac on it. Common iliac and external iliac arteries on affected side twice as large as those on other side.
Potherat (291).......	Femoral	Duration of fistula, 7 years. Artery presents at site of communication a sacciform dilation. This part of artery is very thin. Arterial trunk is dilated above and contracted below.
Graves (308).........	Femoral	Duration of fistula, 6 years. Artery in upper part of Scarpa's triangle and for 2 inches above Poupart's ligament was thinned, dilated, sacculated, and evidently diseased.
Osler (315).........	Femoral	Femoral artery is greatly dilated.
Heuer (336).........	Femoral	Duration of aneurism, 18 years. Dilation of external iliac artery with artery above fistula size of index finger. Thin-walled sac on artery. Hypertrophy and dilation of heart with mitral insufficiency and auricular fibrillation.
Halsted (367)........	Femoral	Duration, 8 years. Sacculation on the artery opposite the communication. Proximal dilatation of the femoral artery.
Northern General Hospital (364)	Femoral	Duration of fistula, 16 days. Common femoral artery was slightly dilated.
Horsley. Case 1 (368)	Femoral	Duration of fistula, several months. Femoral artery was greatly dilated.
Horsley. Case 2 (369)	Femoral	Duration of fistula, a few weeks. Artery was moderately dilated.
Halsted (370)........	Femoral	Duration of fistula, 12 years. Marked dilation of femoral artery. Appears as large as middle finger. Dilation can be traced well up into common iliac artery.
Brainard (374).......	Popliteal	Duration of fistula, 5½ years. Branches of popliteal artery were also enlarged as they opened into sac; 5 of them being large enough to admit a common silver catheter. Coats of artery were thin like those of a vein.
Cock (375)..........	Popliteal	Duration of fistula, 11 years. It is not stated that the popliteal artery was larger than normal but it is said that the popliteal artery was larger going into sac than leaving it. (The deep veins were so extensively thrombosed in this case that arterial blood pressure was probably not much lowered by fistula, and hence there was no dilation of artery.) (W. S. Halsted.)
McLean (378)........	Popliteal	Duration of fistula, 19 years. Clinically femoral artery appears much enlarged. At operation popliteal artery was enormously enlarged. Texture of arteries was so altered arteries looked and felt like veins.

TABLE OF PROXIMAL DILATIONS—*Concluded*

Author and Case No.	Location of fistula	Duration of fistula and description of proximal dilation
Fitzgerald (380)......	Popliteal	Duration of fistula, 15 years. Popliteal artery above aneurism somewhat dilated. Neither profunda nor the anastomotic arteries had undergone any enlargement. Femoral artery greatly dilated, but external and the common iliacs much more so, having a circumference 3 times that of the corresponding vessels on sound side. Dilation ceased promptly at upper end of common iliac in a thin walled, prominent sacculus. Elongation and tortuosity were not less prominent than the increase in diameter. Internal iliac, profunda and the circumflex vessels all remained unenlarged. Noteworthy that superficial femoral vessels were not nearly so dilated as common femoral and iliac vessels, but these are comparatively unsupported, while the former, at least in part of their course, are surrounded by fibre-muscular sheath.
Keyes (381).........	Popliteal	At autopsy popliteal artery was dilated and thinned.
Lucas-Championnière (383)	Popliteal	Duration of fistula, 23 years. Femoral and external iliac arteries remarkably dilated.
von Frisch (415).....	Popliteal	Duration of fistula, 16 years. Femoral artery widened and wall thinned. Popliteal artery not enlarged.
Halsted (390)........	Popliteal	Definite proximal dilation.
Da Costa (424)......	Popliteal	Duration of fistula, 3 months. The artery distal to point of fusion was small, and proximal to same point was much dilated, but not saccular.
Gross (435)..........	Foot	Posterior tibial artery was nearly as large as femoral. "Another interesting instance of proximal dilation of artery with nævus maternus with fistula, or fistulæ." (W. S. Halsted.)
Faguet (437).........	Peroneal	Duration of fistula, 16 days. Peroneal artery dilated above sac, and posterior tibial artery larger than normal.
Parkman (62)........	External carotid	Enlargement of the common and external carotid arteries.
Fraser (74)..........	Temporal	Right occipital and temporal arteries greatly dilated.
Laugier (81).........	Posterior auricular artery	Auricular artery dilated both distally and proximally. Probably is a cirsoid aneurism.
Bankhart (82).......	Facial	Duration of fistula, 2 years and 5 months. The facial artery above and below the jaw was remarkably tortuous and hypertrophied.
Heuer (61)..........	Internal carotid	Internal carotid artery very tortuous.
Halsted (68).........	External carotid	Common carotid artery much larger than usual, but internal carotid artery smaller than normal.

Condition of the Artery Distally.—Unlike the proximal artery where dilatation occurs fairly constantly, that portion of the artery distal to the fistula is usually contracted to much less than its normal calibre. The cause of this is the decreased quantity of blood traversing the vessel in

consequence of the loss of so large a portion diverted into the vein through the fistula.

Among the rare instances of distal arterial dilatation may be mentioned the autopsies done by Breschet on the two femoral aneurisms, in which dilatation extended through the main trunks of the arteries into the capillaries. In the present series of cases, excluding those of Breschet, there were but three instances in which this distal dilatation was noted. In Cauchois' aneurism involving the popliteal, peroneal, and the anterior tibial arteries, there was marked distal dilatation of the anterior tibial artery; while in Baker's aneurism of the femoral vessels involving the profunda artery, this artery was markedly dilated and distended for the first two inches of its length.

Cardiac Complications.—Morvan attributed to Boisseau the first intimation that a cardiac affection may complicate arteriovenous aneurism. In his fistula of the brachial vessels, palpitation of the heart was noted after the case was well advanced.

The most extreme and progressive myocardial insufficiency, occurring after arteriovenous aneurism, occurred in two of Halsted's cases of fistula of the femoral vessels. Up to the time of accident, the patients had suffered absolutely none of the discomforts of cardiac disease. After the formation of the fistula, however, they became thoroughly incapacitated and suffered at various intervals from symptoms of severe myocardial decompensation, and upon examination exhibited an enormous cardiac hypertrophy and dilatation, together with auricular fibrillation and evidences of chronic passive congestion.

The thickening of the inferior vena cava which occurred in Eisenbrey's fistula of eighteen years' duration leads one to consider whether this phenomenon, together with the cardiac hypertrophy and dilatation which accompanied it, might not presumably be the result of increased venous pressure exerted over a long period of years.

One of the most conclusive instances of myocardial insufficiency occurred in Stewart's patient with femoral arteriovenous aneurism in whom, one month following the establishing of the fistula, a systolic murmur was made out over the heart, together with an enlargement of the cardiac outline. A short time after the lateral suture of the artery and vein the heart diminished considerably in size and the murmur disappeared.

Cardiac hypertrophy and dilatation were present in Fitzgerald's popliteal fistula, in Osler's and in Rokitansky's axillary arteriovenous aneurisms, and in Horsley's and in Baker's femoral fistulæ.

Bernard Cunéo, in a recent paper, published an instructive series of venous pressure readings from a case of femoral arteriovenous aneurism. He found that the venous pressure, measured in terms of centimetres of water, was increased not only about the fistula, but in the corresponding vein of the opposite extremity and in one of the veins of the upper ex-

tremity as well. Such a general venous hypertension Delbet considered the causative factor in the production of the marked cardiac hypertrophy and dilatation with accompanying symptoms of decompensation which occurred in a case he recently observed. Toussaint also reported two patients with arteriovenous fistulæ who exhibited similar cardiac phenomena.

V. SYMPTOMATOLOGY

Murmur.—The murmur of arteriovenous fistula is continuous in character, reinforced in intensification with each heart systole, and is propagated in the main in a central direction along the vein, becoming increasingly faint as one recedes or proceeds from the communication. It is heard with maximum intensity immediately over the communication, a circumstance which is a valuable indication as to the exact site of the fistula.

Broca and Henry agreed that the cause of the murmur lay in the vibration of the communication when its borders were set into motion by the continuous passage of arterial blood.

Burckhardt, as well as Billroth, thought that it was caused by the clashing of the venous and arterial columns of blood flowing in opposite directions. Chassaignac attributed to the sound a chemical origin resulting from the mixing of the venous and arterial blood, and Hodgson and Richerand based its occurrence on the friction of the blood on the walls of the communication.

The experiments of Chauveau, Weber, and von Wahl confirmed the speculation of Scarpa in demonstrating conclusively that it, like all vascular murmurs, is of the fluid type, for whose occurrence conditions are here particularly favorable where blood under a certain pressure from the artery flows into a widely expanded vein.

The individuality of this murmur has called forth descriptions from a large number of writers. Bayer compared it to the forcing of air through a syringe, while to Larrey it had the sound of water streaming through metal tubes. Willaume compared it to the noise of a bellows, while to Seeger it seemed like water rushing over a dam and like the whistling of the wind. Ribes likened it to the noise of a mill race. The French call it *bruit cataire* and *bruit de souffle à double courant*, while to the Germans it is the *schwirrendes Geräusch*. Burgess describes it as of the sound of a *fly in a paper box*.

A peculiarity of this murmur is its occasional audibility at a distance without ear contact. In Murphy's and Graves' femoral and Osler's axillary aneurisms it was distinctly heard with the ear six inches away from the affected part.

Thrill.—The rough purring thrill is an evidence that the whirling eddies of blood transmit their vibrations to the thin walls of the vessels; like the murmur it is continuous in character, and has a maximum

systolic accentuation directly over the fistula, with a gradually diminishing intensity as one leaves the point of communication. It must be remembered that the bruit and thrill are only different aspects of the same phenomenon, translated into the medical tongue according to the sense which perceives it. Hunter characterized the thrill as simulating the forcing of water through a narrow opening or the continued whisper of the letter " R." It is the *frémissement vibratoire* of the French.

Cleghorn first placed one end of a metal sound between the teeth and held the other over the tumor and thus combined the palpatory and auditory sensations of the thrill. It was seen experimentally that the thrill spreads through the neighboring vessels with varying intensity and is more strongly felt in the central than in the peripheral segment of the vein.

Venous Pulsation.—Venous pulsation occurs when the arterial pulse wave is transmitted to the venous column of blood and is propagated both peripherally and centrally, together with the murmur and the thrill. From what has been previously said regarding the exclusive anatomic relations of the long saphenous vein, this venous pulsation is not found on a superficial aspect of the lower extremity when the deep veins of the thigh are involved. Franz, in experimentally produced fistulæ in dogs, noted that the venous pulsation was visible for but a few centimetres in a central direction, but that it could be seen peripherally a great distance from the communication.

Pressure Conditions about the Fistula.—Much light has been thrown on the question of the intravascular tension about the fistula by Ney's experimentally produced aneurisms in dogs. His purpose was to emphasize the great importance attached to the central segment of the vein in side-tracking and hurrying away to the heart the arterial blood destined for the peripheral artery and the nourishment of the limb. He observed that the arterial pressure under normal conditions varied between 111 and 115 mm. of Hg, but found that after the formation of the fistula, the pressures in the proximal and distal segments of the artery were equal, varying between 73 and 107 mm. of Hg. The venous pressure he found normally to be between 9 and 11 mm. of Hg, while, with the fistula in operation it showed an average pressure both centrally and distally, between 71 and 105 mm. of Hg, thus establishing a pressure on the venous side but little less than that on the arterial.

Without entering into confusing details one can say that Franz has proved the existence of four different streams of blood flowing through the fistula; the first, running from the peripheral segment of the artery into the central segment of the vein; the second, from the central part of the artery into the central part of the vein; the third, from the central division of the artery to the distal segment of the vein; and the fourth, from the central part of the artery to the peripheral part of the vein. Bra-

mann's observation of a venous pressure reading of 87 mm. of Hg in his aneurism of the axillary vessels is the only evidence of the correlation between animal experiments and fistula in the human.

Phenomena Associated with Venous Obstruction.—A variety of nutritive and other changes is furnished by the obstruction to venous return. The œdematous infiltration and hypertrophy of the extremity in one of the femoral aneurisms of Lannelongue showed a difference in the circumference of the two thighs of 35 centimetres. There occurred an extraordinary degree of œdematous infiltration with the occlusion of the central segment of the vein in the fistulæ of von Wahl in the femoral vessels, of Simon in the abdominal aorta and inferior vena cava, and of Leflaive in the common iliac vessels. According to Matas, œdematous infiltration and hypertrophy of the subcutaneous connective tissue are followed by the subsequent atrophy of the skin, with histologic changes akin to those which accompany varicose vein, while the skeletal muscles undergo atrophy and degeneration.

In the lower extremity, trophic disturbances have occurred in almost all the cases which have been followed a sufficient length of time. Large and painful ulcers were the points of refractory hemorrhages leading eventually to death in Leflaive's case of fistula of the common iliac vessels; while in the femoral aneurisms of Hulke and Billroth, ulceration developed in the course of four years. Absolute incapacity from atrophy and ulceration of the affected member resulted in the femoral aneurisms of Brindejonc-Tréglode.

Spontaneous gangrene of the foot and leg occurred within eight hours of injury in LaGrange's popliteal aneurism, and, although not common, has occurred even after long periods, as was evidenced by the partial gangrene of the hand which took place after forty-two years in Gripat's brachial aneurism.

Hypertrophy of the hair and nails on the affected part has been noted.

Bone and Calcium Deposits in the Vicinity of the Fistula.—Among the most interesting nutritional disturbances associated with arteriovenous aneurism is the effect of such a fistula on bony growth in the vicinity. In certain cases of femoral aneurism, increased length of bones has been noted. In 1854 Giraldès observed in a grown man an arteriovenous aneurism of fourteen years' duration, caused by a stab wound in the thigh, sustained in childhood. Careful examination revealed an increase of 3 centimetres in length of the affected leg which was explained on the hypothesis of *over-development* due to obstructed venous return, one-third of the increase being attributed to the femur, and the other two-thirds to the tibia, the foot being elongated half a centimetre.

This subject has been commented upon from time to time by later writers, notably Cordonnier. He first stressed the fact that in Giraldès' case, as in an identical one of his own, the injuries causing the fistula

were received during adolescence, or the period of life of growing bone. Other instances of the same phenomenon have been recorded. Gwilym Davis mentions a young boy with a femoral fistula produced several years before by an accidental wound of the thigh, during an operation for circumcision. This case was brought to him on account of the marked difference in length between the well and the affected leg. As a result of this and similar instances, he questions whether the production of a fistula might not be a desirable means of increasing the length of limbs in certain cases of shortening due to hip disease and other disabilities.

Sir Prescott Hewett reported a congenital varix of the common iliac vessels in a seventeen-year-old patient, in whom it was perceived that the affected leg was 2 inches longer than its mate. Franz described a case with femoral fistula in which the nutritional changes caused an increase in the length of the member, and remarked that the stimulus exerted on the epiphysial lines is similar to that exerted in young subjects with osteomyelitic changes during the period of growth.

Concomitant Nerve Injuries.—In the regions of the axillary and the subclavian vessels the nerves in the vicinity are particularly liable to injury at the time of the formation of the fistula. In this series of cases nerve injuries were by far most frequent in aneurisms of the subclavian vessels, as, for example, in the cases of Larrey, Wederstrandt, Veiel, Erdmann, Matas, and Pluyette and Bruneau. In the axillary aneurisms they were present in the cases of Bramann, Durmin, and Quénu.

Changes in Surface Temperature.—Faguet and Franz, in femoral fistulæ, noted an increase in the surface temperature immediately over and about the site of the fistula, while Knaak and Bardeleben in axillary aneurism, and Henry in a femoral aneurism, found the surface temperature of those parts peripheral to the fistula decreased. Trélat and Faguet, in aneurisms of the femoral vessels, found the skin temperature elevated at the level of the fistula and decreased below it. The findings of these groups of men were reconciled by Franz's experimental studies which showed an increase in temperature about the fistula, caused by the increased collateral compensation, and a decrease in those parts peripheral to the communication, as a result of the venous stasis.

In general, however, patients complain of a sense of chilliness and cold in the part at or below the region of the aneurism.

Sphygmographic Tracings about the Fistula.—Sphygmographic tracings of the venous pulsation have at different times been recorded. Ebenau, in 1883, and Franz, in 1905, both working with aneurisms of the femoral vessels, took tracings of the pulsation in the femoral vein in which was found a definite *anacrotism* with the temperature well up on a broad summit. This anacrotism was interpreted by Marey as the effect of the arterial blood on the peripheral segment of the vein, and the broad summit was explained on the supposition that the blood streaming into

the vein requires a longer time to stretch its flabby walls to their fullest dilatation. In varicose aneurisms the phenomena may be the expression of the effect of the arterial blood on the walls of the sac.

Cerebral Vascular and Neurologic Disturbances.—Weakness, dizziness, and headache are often associated with fistula of the large vessels of the neck. In Stimson's and Willaume's aneurisms in this region there were marked hearing and visual disturbances, while in Joret's aneurism of the internal carotid artery and the internal jugular vein there occurred a complete paralysis of the right side of the body, with death from epilepsy thirty months later.

Diminished Peripheral Pulsations.—In various cases with diminished peripheral pulsations sphygmographic tracings were made over the peripheral segment of the artery which showed what has been interpreted as a diminished arterial flow.

Tardy Appearance of Signs.—A study of this series of cases establishes the fact that in many instances symptoms and signs either appear late or have not been recognized early. One of the commonest causes for the tardy development of signs is the temporary thrombosis of the vascular wounds. The thrombus may later become dislodged from increased activity or manipulation of the part. With the dislodgement of the thrombus the fistula becomes patent and the intervascular circulation is restored.

In Cooper's aneurism of the femoral vessels the signs made their appearance on the fifth day, while in Robert's femoral aneurism they were delayed six weeks. In Legouest's axillary aneurism signs occurred in eight days, and in Bardeleben's axillary aneurism no signs appeared until after two and a half weeks. In the aneurisms of the subclavian vessels the signs on the average were noted after about six days. The recording of the varying times of the appearance of signs suggests a lack of uniformity in their observation.

Symptoms Induced by Proximal Compression of the Artery.—Some observers in their careful analyses have noted a peculiar set of circulatory phenomena dependent upon proximal compression of the artery. The most mysterious feature in this connection occurred in Branham's aneurism of the femoral vessels, in which case proximal compression of the common femoral artery slowed the heart so markedly as to cause its rate to drop from eighty to thirty-five beats a minute, and so to remain until the pressure was released. Compression on the artery on the sound side produced no such effect, while the examination of the heart showed it to be free from any valvular trouble. Associated with the slowing of the heart beat, dizziness, dyspnœa, and distress were noted. Compression of the proximal femoral artery in Huguier's aneurism caused syncope, while in Schwartz's aneurism it produced agitation, cyanosis, and intense dyspnœa, all of which disappeared with the cessation of pressure. Pres-

sure on a carotid artery in Beach's patient with temporal aneurism produced sensations of dizziness and distress, while slight compression over the subclavian artery in Breschet's aneurism in that region caused a feeling of discomfort about the right side of the head and in the right eye. Pressure over the tumor in Cordonnier's and Henry's femoral aneurisms elicited a pain in the heart.

Initial and Secondary Hemorrhage.—Although the initial hemorrhage occurring in Rotter's subclavian and in Halsted's and Horner's femoral aneurisms resulted in syncope, the bleeding in most instances ceased spontaneously or as a result of light compression.

The most important factor in its spontaneous arrest is the infiltration by the extravasated blood of the muscular sheaths immediately around the wound canal, leading to its obliteration. Moreover, where severe primary hemorrhage has occurred with the consequent fall in blood pressure, clot formation is favored both at the point of vascular injury and at the wound's external orifice.

When the secondary hemorrhage occurs during the first week after injury it is rarely of any importance, for it is usually little more than leakage from a small wound during the early contraction of the hæmatoma. When there is, however, a rapid extension of the swelling, one must suspect that type of secondary hemorrhage that probably depends upon the defective process of localization which has allowed some part of the limiting boundary of the false sac to give way. A sudden rise in blood pressure, accompanying increased activity, or perhaps the free movement of the limb, may be its cause (Makins).

Secondary Arteriovenous Aneurism.—A special study of the aneurisms arising from the regions of the sinuses of Valsalva, in the pericardial portion of the aorta, is worth while because of the effect they produce on the neighboring organs. They compress, obliterate, and even form communications with the large venous trunks with which the aorta is surrounded, and thus constitute secondary arteriovenous aneurisms of an extraordinary character. They even burrow into the musculature of the heart itself and have ruptured into the right ventricle, right auricle, and pulmonary artery.

We find an occasional example of rupture from some unusual effort or exertion, but these communications have usually resulted from a gradual softening or ulceration of the walls of the sac. The clinical picture is characterized by a sensation of something giving way in the chest, a feeling of faintness, dyspnœa, and palpitation of the heart, and very decided signs of obstruction to the venous circulation. The face is usually livid and bloated; there is widespread œdema of the tissues in all the cases in which death does not supervene too rapidly, and the anasarca involves all parts of the body whose veins are distal to the communication. If the aneurism of the ascending aorta be in communication with the

superior vena cava, the œdema of the face and arms stands in remarkable contrast to the normal appearance of the lower half of the body. When, on the other hand, the abdominal aorta and the inferior vena cava are the seat of the fistulous communication, the œdema of the legs and the lower half of the body is in marked contrast with the unswollen condition of the arms. When the aneurism erodes the appendix of the right auricle, the right ventricle, or the pulmonary artery, the venous system of the whole body distal to the orifice of the communication shows the condition of general anasarca.

VI. DIAGNOSIS

In this period of modern destructive warfare with the inevitably large numbers of concealed vascular wounds, a careful search should be made for all possible pathological intervascular communications; of great aid in recognizing them is the carefully ascertained history of injury over the vascular tracks.

The cardinal symptoms are a loud, continuous, reinforced murmur with a central and peripheral propagation; a purring, reinforced thrill; and definite venous dilatation and pulsation at the site of injury. When these are present the diagnosis of arteriovenous aneurism should present no difficulties.

Differential Diagnosis as to Variety.—According to Francke, the aneurismal varix appears about three or four days after the injury in the form of a soft, fluctuant tumor, oval in shape, and usually about the size of a hazelnut, increasing very gradually in size, and which may be obliterated with light pressure.

The varicose encysted type of tumor is harder, firmer, and less fluctuating, and although made smaller by pressure, it will not altogether vanish. It is irregular in form and its size varies within wide limits; it is not enlarged by the compression of the artery above, or diminished with the elevation of the member.

The varicose aneurism by dilatation may be differentiated by the fact that the tumor is less prominent, fusiform in shape, soft to the touch, completely disappears on direct compression, and is diminished in size by the elevation of the part.

Differential Diagnosis from other Conditions.—From arterial aneurism the arteriovenous aneurism may be readily distinguished. In the arterial aneurism the murmur is not constant, but when present is systolic in time and therefore intermittent.

In cirsoid aneurism the thrill may be absent or barely palpable, while the afferent and the efferent arteries, together with their branches, are all enlarged and tortuous. The murmur, if present, is weak, lacking the systolic accentuation, and pressure above the aneurism will not cause the murmur or pulsation to vanish. Its general location is about the head,

face, and neck, and in vessels of smaller calibre than those in which arteriovenous aneurisms occur. It is always of spontaneous origin and frequently occurs in association with nævi.

VII. PROGNOSIS

Observers from the time of Hunter until the present have expressed varying opinions as to the prognosis in this affection. The consensus of opinion is that the condition is always embarrassing, often incapacitating, and occasionally leads to serious results.

Prognosis According to Variety.—Some writers have differentiated the severity of the prognosis in accordance with the variety of the anuerism. According to Scarpa, the aneurismal varix can be borne with impunity if it be not subjected to frequent violent and unusual efforts, whereas the varicose aneurism tends to enlarge and cause pressure disturbances. Many of the later authors, Bayer, Cooper, Nélaton, Richet, Bardeleben, and others have accepted Scarpa's analysis of the prognosis according to variety.

According to Delbet, however, Scarpa meant by his varicose variety only that type of fistula in which the false sac lies between the artery and the vein, namely, in the type known as the *intermediate encysted varicose aneurism*. The authors mentioned above, however, gave a bad prognosis in all aneurisms possessing any circumscribed dilatation on the artery, the vein, or the channel of communication. In view of the fact that most cases of simple aneurismal varix sooner or later show saccular dilatation, it is difficult to see how a clean-cut differentiation between these two main varieties may be made.

Francke, Delbet, and Bramann considered the dangers caused by the varix to be as great as those belonging to the varicose type.

Prognosis as to Duration.—The prognosis must be modified by the knowledge that the presence of fistula is not incompatible with long life. Among the cases in which the condition has existed for periods exceeding twenty-five years are the following: Schottin's aneurism of the vessels of the wrist was present for fifty-five years; Gripat's brachial aneurism lasted forty-two years; Moore's aneurism of the temporal vessels was present for thirty-six years; Hunter's brachial aneurism for thirty-four years; Gallerand's femoral aneurism lasted thirty-two years; Heuer's femoral aneurism was present twenty-eight years; and Queitel's common carotid aneurism for twenty-seven years.

Prognosis as to Progressive Danger.—It must be borne in mind that there is a potential progressive danger from enlargement and rupture of the tumor. Sale's aneurism of the internal carotid artery and the internal jugular vein resulted in a hemorrhage and death in eight months after a long period of threatened rupture. After a remission of sixteen years a sudden enlargement resulted in gangrene which caused the death of

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Broca's patient with brachial aneurism. Rokitansky's axillary aneurism remained stationary thirty-three years, after which it suddenly enlarged and necessitated operation, while Gripat's aneurism of the brachial vessels after a duration of forty-two years developed a sudden enlargement causing gangrene of the fingers. Annandale's aneurism grew to the size of an infant's head in the short period of three months, and an enormous tumor was present within four weeks after injury in Czerny's femoral aneurism. The brachial aneurism in Park's case enlarged to the size of a fist and finally ruptured.

Gerdy and Broca have insisted on a more serious prognosis with aneurisms of the lower extremity.

VIII. TREATMENT

Non-operative.—The development of the treatment of arteriovenous aneurism from Guattini, in 1785, up to the present date is one of gradual progression. The earlier years were not the years of surgery and the physician's armamentarium was limited to therapeusis, manipulation, and pseudo-operative procedures.

Injection of Coagulating Fluid.—The knowledge that certain chemicals possessed blood coagulating qualities, and the hope that a coagulum resulting from their use would block off the fistula, led to the injection into the sac of the aneurism of perchloride of iron. Failure attended its first use in Velpeau's brachial aneurism, and death followed in Pravatz's brachial aneurism, in which its use rendered amputation necessary. Although two injections of this chemical cured Jobert's aneurism, the dangers from gangrene and secondary hemorrhage do not warrant its employment in this type of case.

Galvano-puncture.—Cures following galvano-puncture may in most instances be attributed either to the compression which has preceded or the inflammation which has followed its application. The consequent gangrene from detached emboli and severe hemorrhages and infections, coupled with its rare cures, make its use in the treatment of arteriovenous aneurism entirely unjustifiable.

Medicinal Treatment.—Possibly the earliest therapy was the application to arteriovenous aneurism of Valsalva's precepts in arterial aneurism. This treatment consisted in repeated venesection and purgation, in conjunction with digitalis therapy and scanty diet, in the hope that spontaneous coagulation of blood about the fistula might take place. Such treatment brought no satisfactory results.

Indirect Compression.—Of the bloodless methods of treatment the varieties of compression, both direct and indirect, have been most extensively and successfully employed. *Indirect compression* is that which is exerted upon the afferent artery and not over the aneurismal tumor, and

has for its purpose the spontaneous coagulation of blood in the anuerismal sac. Of the different forms of compression, it is the least painful and may be the longest continued without interruption. According as the pulsation of the tumor is diminished or made to disappear altogether, the compression is termed partial or total.

Direct Compression.—In instituting direct compression of the *instrumental* variety, a tampon is securely bound immediately over the orifice of the communication. The intolerable pain and the occasional accidents from trophic disturbances, together with its unreliability, are the main objections to this method.

The adoption of the *digital* variety of direct compression is attributed to Vanzetti, of Padua, who cured several brachial aneurisms by this method of prolonged pressure with the tip of the finger immediately over the tumor as near the communication as possible. The treatment was instituted as a means of stimulating collateral circulation in preparation for a future ligation, but it should be remembered that cures have been obtained in but a few brachial aneurisms of very recent origin, and that in some instances it has exposed the tumor to inflammation and rupture with a subsequent gangrene of the part.

In this series of cases compression was attempted in all locations and varieties of aneurisms in 61 instances; 9 patients were cured, 3 died, and in the remainder the procedures were failures. Of the cures 7 occurred in brachial aneurisms, 1 in Trélat's femoral aneurism, and 1 in Geschwind's axillary aneurism.

Guattini, in 1785, using a combination of the direct and indirect methods of compression, has to his credit the first cure of brachial aneurism. Other cures are attributed to Vanzetti, Monteggio, and Brambilla.

Considerable interest has arisen regarding the possibility of transforming arteriovenous aneurism into arterial aneurism by the obliteration of the communicating fistula. In 1809 Scarpa conceived the idea of obliterating the point of communication between the two vessels, for he wrote: " In a favorable case in which the exact opening in the vessels may be brought into union against the bony walls, and the pressure here maintained for a sufficient length of time, there is no reason to suppose that the firm mass of the adhesive tissue will not seal off the opening with the resulting cure of the patient." Brown, in 1836, thought that " a gradual, prudent compression in young subjects may bring about an adhesive inflammation which will determine the obliteration of the opening between the artery and the vein." Nélaton, in 1846, first accomplished this result.

Inflammation of the sac is the most common accident resulting from compression. In Spence's case of femoral aneurism it necessitated operation, and in Carafi's femoral fistula compression on the communication was followed by gangrene. Death following compression was the out-

come in Gallerand's femoral aneurism, while compression of the abdominal aorta and inferior vena cava in Simon's aneurism caused peritonitis from intestinal gangrene.

Operative Treatment—Hunterian Ligation.—Hunterian ligation, or the proximal ligation of the artery at a distance from the fistula, was practiced in 32 cases in this series, resulting in 5 cures (15.6 per cent.), 19 deaths (59.3 per cent.), and 8 instances of gangrene (25 per cent.). Recurrence constituted the majority of the failures. Three cures of femoral aneurism were reported by Korlowski and Bickham after ligation of the external iliac artery, and by Freyer after ligation of the common femoral artery. A cure resulted in Stromeyer's popliteal aneurism.

Deaths from hemorrhage or infection occurred in the femoral aneurisms of Gayet, Lannelongue, Paguet, and Perry, in the brachial aneurisms of Schuh and Piragoff, and in the axillary aneurism of Rokitansky. Death from gangrene and infection occurred in Socin's and Graves' femoral aneurisms. Deaths from hemiplegia are noted in Prince's aneurism of the common carotid artery and the internal jugular vein, and Holston's aneurism of the carotid artery and the external jugular vein. Gangrene caused death in Fitzgerald's aneurism of the popliteal vessels, and in Robert's femoral aneurism. Death followed the ligation of the external or common iliac arteries in the aneurisms reported by the following men: Venturoli, Gayet, Roberts, O'Grady, Hutchinson, Lannelongue, Graves, and Faguet. In Bramann's table of 31 Hunterian ligations, only 6 were successful, or 19.3 per cent. There were 8 cases of gangrene, or 25.8 per cent.

Delbet reported 40 cases treated by proximal ligation, among which there were 10 cures, or 25 per cent., 9 deaths from gangrene, or 22.5 per cent.

Bardeleben has the following to say about gangrene: " If we could by means of asepsis guard against wound infection and inflammation, we should still be unable to regulate the collateral circulation."

According to Matas, there are the following disadvantages to Hunterian ligation:

A. *The liability of gangrene of the limb is increased by:* (1) the interposition of two obstacles to the path of the blood from the cardiac side to the periphery; first at the seat of ligature and secondly at the site of the aneurism, which is totally or partially blocked off by clots after the ligation; (2) by putting out of function a large number of important and often essential collateral branches, given off from the main trunk between the ligation and the aneurism, in some cases the track of the artery being obstructed by a thrombus for a great part of its length after the ligation; (3) in consequence the blood has to pass through two sets of collaterals before it can reach the part beyond the sac; (4) the risk of gangrene, therefore, increases in direct ratio to the distance between the ligation and the sac; (5) the risk of obstruction of the distal end of the artery by emboli, or propagated thrombi, is greatest in Hunterian ligature, which aims at the gradual and not the immediate suppression of the circulation of the sac, the minor circulation in the sac resulting from previous collaterals which empty into the main trunk above

the sac favoring the increased deposition of active clot, and also breaking up the new, soft and passive clot formed temporarily by the ligation of the main trunk.

B. *The reëstablishment of the collateral circulation* after ligation at a distance may carry more blood into the main artery between the ligature and the sac, and thus lead to recurrence.

C. *There is no advantage in ligating the artery at a distance;* because (1) the simple aseptic ligature strengthens the artery at the seat of ligation, and there is no secondary hemorrhage when there is no suppuration; (2) it has been shown that the arteries are often quite healthy immediately above the aneurism (especially in the traumatic cases).

D. *The danger of infecting the sac* by the manipulations required to ligate the artery at its termination in the sac is not to be considered in aseptic operations.

Ligation of Anel.—Scarpa was the first to advise the proximal ligation of the artery in the immediate vicinity of the sac as an improvement over the Hunterian ligation. Its advantages are that it shuts off the circulation at once and allows the fluid contents of the sac to drain away completely, allowing whatever laminated clot is present to remain. The volume of the sac is diminished and the tendency is less for the passive clot to break up (Matas).

In 16 cases of ligation of this type there were 7 cures, or 43.7 per cent., 4 deaths, or 25 per cent., and 3 cases of gangrene, or 18.7 per cent. Death from gangrene occurred in Horner's and Bloch's femoral aneurisms, and gangrene in Lewtas' case demanded amputation.

Double Arterial Ligation.—Proximal and distal ligation of the artery in the immediate vicinity of the sac, better known as double arterial ligation, was first successfully employed by Norris in 1843. Malgaine, in 1852, and Dupuytren before him, approved the operation. It has been performed thirty times in this series, with 17 cures, or 56.6 per cent., 3 deaths, or 10 per cent., and 3 instances of gangrene, or 10 per cent.

Hemorrhage and infection were the cause of death in Page's and Cooper's femoral aneurisms, and death followed amputation for gangrene in Joyce's femoral fistula. According to Broca, the operation will be successful if the strip of artery between the ligatures contains no collateral branches.

Quadruple Ligation.—Proximal and distal ligation of both artery and vein, or quadruple ligation, has been practiced in 27 cases, from which there resulted 21 cures, or 77.7 per cent., 2 deaths, or 7.4 per cent., and 4 instances of gangrene, or 14.8 per cent. Death from gangrene occurred in Pieri's femoral and in McLean's popliteal aneurisms. Amputation and recovery followed gangrene in Eccles' and Duval's aneurisms of the femoral vessels.

Incision of the Sac.—When the operation of Antyllus, or the incision of the sac, is performed, the afferent and the efferent vessels are first ligated securely outside the sac, which is then incised and its contents evacuated, and a search made for any entering collaterals. If such are

found, they are ligated on the periphery of the sac and the cavity is packed.

In 16 cases of this variety there were 8 cures, or 50 per cent., 5 deaths, or 31.2 per cent., and 3 cases of gangrene, or 18.7 per cent.

While some claim the two advantages of incision of the sac to be the ability to empty the sac of clots and the increased facility for search of the collateral vessels, Delbet considers these advantages of little moment, because clots in the sac are rare, and because the search for the collaterals is really not facilitated. Among the chief objections to the method are the astounding secondary hemorrhages which may result from collaterals so small as to be unsuspected during the operation, and the delayed wound closure from the abandoned sac. Moreover, the calcareous plates, which so often line the sac, act as foreign bodies and interfere by their pressure with the perivascular nutrition, while the danger from disseminated emboli always remains.

Extirpation.—The operation of the complete extirpation of the aneurism after quadruple ligation of the afferent and efferent vessels, with its high percentage of favorable results, must be duly accredited (Fig. 11). In 122 such operations there had been 117 cures, or 95.9 per cent., 1 death, or .8 per cent., and 1 residual gangrene, or .8 per cent. Death occurred in Barendrecht's case in the popliteal vessels, and failure resulted in Jaboulay's case of posterior tibial aneurism. Among the cases of improvement may be mentioned the popliteal aneurism operated upon by von Eiselsberg, in which there were residual plaques of gangrene of the foot, and Bornhaupt's aneurism of the popliteal vessels with residual motor and sensory changes, and von Eiselsberg's brachial aneurism, which showed symptoms present after three years. In this type of operation the disadvantages of tardy healing and imperfect hæmostasis, as well as gangrene from pressure on arterial collaterals, which in other operations are so major, are here reduced to a minimum. By careful dissection one may obviate the useless section of adherent nerves and vessels, whose loss plays so important a rôle in the formation of residual nerve and trophic disturbances. In general, it fulfills all the requirements, presents the least danger, and has given up to the present the best results.

Conserving Operations.—Most writers agree that the ideal operation is that which maintains the continuity of the vascular paths, and the procedures which serve this purpose are here described under the caption *conserving operations.* The continuity of one or both vessels may be maintained by three methods; ligation of the communication, lateral suture, and end-to-end suture.

1. *Ligation of the canal of communication* is possible only in cases where the communication is short and easy of access (Fig. 12). It has been successfully performed by Cranwell in a popliteal aneurism, and by Weigel in a brachial aneurism. Delbet was successful in ligating the communication, but the resulting arterial varix necessitated extirpation.

Ligation of the communication with a double ligation of the vein was done in the two brachial aneurisms of Van Ischmoot, and Boddaert and Vercauteren. Ligation of the communication with a double ligation of the artery was successful in Westergaard's femoral aneurism and in Erdmann's subclavian aneurism. This operation was successfully performed by Berkeley and Bonney in an aneurism of the subclavian vessels, until hemorrhage, which followed suppuration from the replacement of the resected clavicle, necessitated ligation of the innominate artery.

2. Up to 1917, exclusive of war statistics, *lateral suture of the artery and vein* has been attempted in 10 cases, resulting in 8 cures and 2 deaths. The cures are attributed to Veau in aneurism of the axillary vessels, Wiessinger and Körte in popliteal fistulæ, and to Ray in an aneurism of the anterior tibial vessels. Cures in aneurisms of the femoral region are claimed in the cases of Gessner, Stewart, and Halsted. The femoral fistula, located in Hunter's canal, operated upon by Doctor Halsted, was of particular interest. Together with the characteristic symptoms of arteriovenous aneurism there were exhibited marked swelling of the affected leg and the presence of many healed ulcers. The treatment consisted of lateral suture of the artery and the vein. Heuer successfully sutured the femoral artery and vein in a femoral aneurism, but was unfortunate enough to lose his patient on the forty-fourth day from empyema complicating pneumonia, contracted in the hospital. Hemorrhage followed Horsley's double lateral ligature of the femoral vessels, for which a ligation of the external iliac artery was later done, the patient, however, dying from an acute myocardial decompensation.

Lateral suture of the artery and double ligation of the vein has been done in three cases. Zoege von Manteuffel, in removing an ossified femoral aneurism intimately connected with the femur, sewed two rents made in the artery and one in the vein, after which the vein and the tumor were resected. Garrè in a femoral aneurism and Doyen in a brachial aneurism doubly ligated and resected the vein with the tumor attached after the lateral suture of the artery. Lateral suture of the vein with double ligation of the artery was successful in Montaz's femoral, Matas' subclavian aneurisms, and in Newbolt's popliteal aneurism. In Greiss's femoral aneurism, a double arterial ligation and resection was performed and the segment was used to reinforce the lateral suture of the vein. Improvement resulted from this treatment in Halsted's femoral aneurism. The one failure occurred in Auvray's ligation of the communication, following a lateral suture of the artery.

End-to-end suture of the artery with the resection of the vein was accomplished by Garrè in a popliteal aneurism, while end-to-end suture of the artery and lateral suture of the vein was accomplished by Murphy. Godwin performed an end-to-end suture of the vein and a lateral suture of the artery, which latter he reinforced with a segment of transplanted

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internal saphenous vein (Fig. 13). Da Costa, in an aneurism of the popliteal vessels, made a lateral suture of the artery and an end-to-end suture of the resected vein, reinforcing the lateral suture with the segment of the resected vein (Fig. 14).

Preliminary Test of the Collateral Circulation.—The Korotkow blood-pressure test for determining the efficiency of the collateral circulation consists in compressing proximally the artery leading to the aneurism, and while maintaining this pressure, estimating the blood-pressure in the peripheral circulation, such as the finger. The height of the blood-pressure thus found in the peripheral arterial segment furnishes the true indication as to the adequacy of the collateral circulation. Thus it may be determined whether an obliterative operation may be undertaken.

The advantages and disadvantages of Korotkow's test are aptly illustrated in the axillary fistula of von Oppel. When he compressed the axillary artery in this case immediately above the aneurism, the blood-pressure reading in the peripheral artery was 40 mm. of Hg. A prognosis of a sufficient collateral circulation was therefore made, and an operation undertaken. It may be said that, near the tumor, two brachial veins opened into a much dilated axillary vein.

In the first operation, after the axillary artery was divided proximally, the blood-pressure in the finger was found to be zero and the limb became pale. Considering the collateral circulation adequate, however, the wound was closed, but the peripheral pressure did not return and the forearm and hand blanched. It was then thought that the arterial blood had returned to the heart by way of the before-mentioned superficial axillary vein.

In a second operation this vein was ligated both distally and proximally, but the blood-pressure in the finger still remained at zero. It was certain, then, that some deep accessory vein carried the blood to the heart, for when compression was made in the wound between the stumps of the divided artery, the arm became red and the pressure in the fingers rose to 40 mm. of Hg. It was concluded, then, that some deep vein in the neighborhood of the artery had also been obliterated by the digital pressure, and that this vein was the one carrying the collateral blood back to the heart. Further search revealed such a deep vein which von Oppel now ligated and divided centrally. The pressure in the fingers then returned to 40 mm. of Hg. Following the removal of the bandage, however, the hand again paled and the blood-pressure dropped to zero, a phenomenon which can only be accounted for by the widening of the collateral paths.

Since the collateral paths had widened and diverted the arterial blood to the heart, a third operation was performed on the same day and the sac was excised entire, with the resulting cure of the aneurism.

IX. EXPERIMENTAL ARTERIOVENOUS ANEURISM

Amussat, in 1843, was the pioneer in the field of experimental arterio-venous anastomosis, and he produced in horses several varieties of varicose aneurisms. No further experiments on the subject were made, until, in 1878, Francois Franck studied its production from the standpoint of practical application to the clinical course and symptomatology of the condition. Vignolo, in 1902, and Franz, in 1905, experimented along similar lines, and the work of the former was the basis of those who followed. San Martin and Satrutegui produced fistulæ on goats and had the courage to use their method in the treatment of two patients with senile gangrene, in the hope of opening up new paths to the arterial blood. Both operations, however, were unsuccessful, and amputation became necessary. Stimulated by Jaboulay, Carrel, in 1902, developed his circular arteriorrhaphy, with which he reversed the circulation in various parts of the body and trans-formed veins into pulsating arteries, and arteries into flaccid veins.

THE TREATMENT OF MALIGNANT TUMORS OF THE THYMUS GLAND BY RADIUM

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During the past year a number of patients with primary new growths of the mediastinum have been referred to the Memorial Hospital for treatment with radium. In the case of one of these patients it has been possible to settle the diagnosis exactly by examination of a portion of the tumor removed for microscopical section. Three other patients came to autopsy and an opportunity was thus afforded to study satisfactorily not only the histology of their tumors, but the relations of the primary growth and its extensions through the body. In each of these four cases the diagnosis of a primary malignant new growth of the thymus gland was established by Dr. James Ewing, who made the pathological examination and has reported one of them, and two others not observed by the writer, in a recent article in which he called attention to this group of tumors, thoroughly discussed their histology, and collected and reviewed the literature.[1] In two other advanced cases observed by the writer the diagnosis was made from the close resemblance of their clinical course and objective findings to the cases coming to autopsy and proved by microscopical section. Finally, three additional cases which ran a more benign course and came to us at an earlier stage of the disease are herein reported. In these cases, also, the diagnosis rests on the clinical data. The significance of these last three cases, however, is great, for two of them have remained well for long periods since their treatment by radium, one of them for a year and a half, and another for almost a year; the third has only recently been treated.

These results indicate that we have in radium an agent by which we may hope to produce a cure of certain malignant new growths of the thymus gland; and inasmuch as our experience indicates that malignant new growths of the thymus gland are more frequent than has generally been supposed, one should constantly bear in mind the possibility of their presence when studying patients with early thoracic affections.

The probability of obtaining a favorable result in the treatment of these tumors depends not only upon the early diagnosis and application of treatment, but quite as much upon the variety of the tumor with which we have to deal. Ewing states that " pathologically these tumors fall into two main groups:

" 1. Lymphosarcoma—composed of a diffuse growth of round polyhedral and giant cells.

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[1] Ewing, James: The Thymus and Its Tumors. Surg., Gynec. and Obstet., 1916, April, p. 461.

" 2. Carcinoma—in which the main tumor cell is a pavement, cubical, or, rarely, cylindrical epithelium.

" 3. Very rarely, spindle-cell or myxosarcoma—believed to arise from the stroma of the gland—may be encountered.

" Of these varieties the lymphosarcomas are by far the most frequent. They vary all the way from a process akin in structure to a granuloma with a more limited and slower growth, to a very malignant rapidly-growing tumor composed of a diffuse growth of small round cells in which reticulum cells are largely missing. No attempt has been made in the past to distinguish these tumors from other lymphosarcomas." Ewing emphasizes, however, the fact that on close analysis the round-cell tumors of the thymus are found to differ in structure from the round-cell tumors of lymph-nodes. " The lymphocytes are scanty. The chief cell showing mitosis is often polyhedral with acidophile cytoplasm, vesicular nucleus, and well-developed nucleoli. They often cling to the walls of numerous small capillaries where they assume a cubical or even a cylindrical form. They may produce abortive Hassall's corpuscles. The giant cells are of two main types: (1) Pole-staining reticulum cells with irregular outlines distended with vacuoles and red-cell detritus; and (2) myeloid giant cells with opaque acidophile cytoplasm and many vesicular nuclei. These giant cells differ from the smaller giant cells of lymphatic Hodgkin's disease. The marked fibrosis suggests the desmoplastic property of carcinoma."

" Thymic carcinoma, a much rarer tumor, preserves more perfectly in its cells the epithelial structure. These tumors tend to remain local, though they may produce metastases. As a rule, they exhibit far less tendency to erode surrounding organs than is usual with carcinoma."

The favorable results obtained in the cases of our series which are still well for a year to a year and a half depend, no doubt, upon the fact that these tumors belonged to the less malignant type of lymphosarcoma. The result to date in the case still under treatment, Case IX, though definite, is less marked than was the state of affairs for the same length of time in the other two cases coming for treatment while their tumors were still small. This third early case probably represents a different type of disease histologically. It may belong to the carcinomas. Nevertheless, the results in these three cases, as well as the profound impression made upon the more malignant and rapidly-growing forms illustrated by Cases V and VI, strongly urge the importance of an early diagnosis and familiarity with the clinical course of these tumors.

The first symptom is usually cough without expectoration or hæmoptysis. The cough may be associated at the very first, or very early in its course, with dyspnœa. In the very beginning the majority of these cases are regarded as tuberculous processes in the lung. This was so in the three cases of our series which gave the favorable results under radium treatment. There will be with thymoma an absence of physical signs in

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the apices and dullness over the centre of the upper portion of the sternum. If these cases are treated for prolonged periods as tuberculosis, they may lose—depending upon the rapidity of the growth—the opportunity of a very material benefit from treatment by radium. In other cases, the dyspnœa is the pronounced symptom from the start and increases so rapidly that with a very cursory examination it is evident from the beginning that one is dealing with a tumor of the thorax. The very malignant cases of this type may run their course in three or four or even two months' time. The majority of the cases of lymphosarcoma of the thymus metastasize and form extensions into the lung and pleura, and the very malignant cases do so early in their course. Extension through the anterior wall of the chest or through the sternum is characteristic. It has occurred in three of the cases in the present series, has been commented on by other observers, and appears to be of frequent occurrence.

Enlargement of the axillary lymph-nodes may occur before involvement of the cervical nodes; or enlargement of the axillary lymph-nodes may be out of all proportion to the involvement of the cervical nodes. Such rapid extension to the axillary nodes suggests lymphosarcoma of the thymus. As the disease progresses, the dyspnœa becomes extreme, the infiltration into the lungs and pleura increases, hydrothorax develops, the heart becomes displaced, and the large intrathoracic vessels and trachea and bronchi become seriously compressed, with consequent cyanosis and venous congestion of the upper chest, neck, and head. In a special group of cases the blood picture may early resemble that of lymphatic leucæmia. In fact, this diagnosis was made in one case referred to us. Metastatic extension into the abdominal lymph-nodes and organs is frequent, but rarely acquires sufficient headway to cause symptoms before death occurs from pressure within the thorax.

In all cases X-ray examination is the one aid to diagnosis which is of the utmost importance. The location and the appearance of the shadow are characteristic. It is immediately above the pericardium, higher than the usual location of that due to enlargement of the peribronchial glands. The character and the location of the shadow are well shown in the radiographs of the cases herein reported, particularly in Cases VII, VIII, and IX.

The radiograph is thus a valuable means of diagnosis. Many of these cases have hitherto been classed as mediastinal Hodgkin's disease or lymphosarcoma of the mediastinal lymphatics, but most of the true cases of mediastinal Hodgkin's disease have exhibited invasive characters which have aroused the suspicion that they were thymomas. Such errors, however, are not of great practical importance, as both Hodgkin's disease and true lymphosarcoma of the lymphatic glands are best treated by radium.

In conclusion it may be stated that: (1) Malignant new growths, particularly lymphosarcomata of the thymus gland are of more frequent occurrence than has hitherto been believed. (2) Radium offers to patients

with this disease a real relief, and in certain cases even a prospect of cure. (3) Every effort should be made to treat these cases with radium during an early stage, and, in order to do this, the possibility of malignant disease of the thymus should be considered and a radiograph taken in the earliest stages of all intrathoracic affections.

CASE I.—Mary D., aged forty-eight years, No. 23678, applied for treatment November 15, 1916. Her present illness began in February, 1916, with the appearance of a nodule at the middle of the sternum. The nodule was hard but not tender. It gradually increased in size. Shortly afterward a slightly enlarged gland was noticed just above the sternal notch. In May, pain began to be felt in the sternum, and in June the sternal tumor had increased considerably in size, involving then the entire region of the upper part of the sternum and its right costal margin. The patient then received X-ray treatment and two radium treatments. The mass diminished in size, but the axillary lymph-nodes on both sides became much enlarged and later the left cervical lymph-nodes.

Examination.—The region of the upper portion of the sternum is the seat of a new growth extending from ½ inch above the sternum to a point 6½ inches below. From side to side it extends from the left margin of the sternum to a point 4 inches to the right of the sternum. The mass is elevated ½ inch above the surface of the surrounding chest wall. The most prominent point is at the juncture of the manubrium and gladiolus, just to the left of the middle line, where the tumor is 2½ inches high. The overlying skin at the summit of this portion of the mass is necrotic. Immediately above the sternal notch is a lump ¾ inch in diameter. Beneath the middle of the left sternomastoid muscle is a gland the size of a hickory nut. In both axillæ are nodular masses the size of oranges.

Microscopical examination by Dr. James Ewing of a piece removed from the sternal tumor for section in February, 1917, shows a tissue composed of dense hyaline connective-tissue bands and masses of tumor cells in their meshes. These cells are as small as or smaller than lymphocytes. Their nuclei are very hyperchromatic. Traces of cell body stain with eosin. Some cells are larger and polyhedral. There are no giant cells nor traces of thymus nodules or corpuscles.

Diagnosis.—Diffuse round-cell thymoma.

Treatment.—November 17, 1916: 540 mc., in 12 3-mm. lead tubes, applied over the sternum, at a distance of 2 cm., for three hours.

November 18, 1916: 864 mc., in 12 3-mm. lead tubes, applied, at a distance of 2 cm., for two hours, over the sternum.

November 23, 1916: 500 mc., in 5 tubes of 1-mm. platinum, applied, at a distance of 5 cm., to the left axilla for four hours.

November 24, 1916: 450 mc. applied, in 5 tubes of 1-mm. platinum, at a distance of 5 cm., for four hours, to the right axilla.

November 25, 1916: The mass in the sternum has practically disappeared.

November 26, 1916: 384 mc., in 12 tubes of 3 mm. of lead, applied, at a distance of 2 cm., to the left side of the neck for ten hours.

December 6, 1916: Examination of the chest shows a marked improvement. The tumor has practically gone. A hard mass is palpable just above the left clavicle, about the size of a hen's egg.

Further Treatment.—December 16, 1916: 600 mc., in 12 tubes of 3 mm. of lead, applied, at a distance of 2 cm., to the right side of the neck, for three and one-half hours.

December 20, 1916: 480 mc., in 12 tubes of 3 mm. of lead, applied, at a distance of 2 cm., to the right shoulder, for four hours.

December 21, 1916, 720 mc., in 12 tubes of 3 mm. of lead, applied to the right axilla, for six hours.

January 1, 1917: 480 mc., in 12 tubes of 3 mm. of lead, applied, for eight hours, to the right side of the neck.

This second series of treatments produced only a very temporary improvement. The patient died on February 6, 1917.

Autopsy by Dr. James Ewing showed a primary thymoma.

The body is that of a rather poorly-nourished female. There are three ulcerated areas on the anterior surface of the chest, each 1½ inches in diameter, and probably due to the action of radium upon tumor tissue.

On cutting through the skin we come to tumor tissue directly below the skin, which leads down through the sternum to the mediastinum. This extends from the sternoclavicular joint down to about the centre of the sternum. The upper half of the sternum is destroyed by tumor tissue. There is a large mediastinal tumor, which is about 4 inches broad and 6 inches long, which extends into both lungs and axilla. Heart is negative; liver and spleen contain metastases; the kidneys show a diffuse granular nephritis.

The tumor is composed of diffusely-growing small round cells, resembling lymphocytes, with very hyperchromatic nuclei.

CASE II.—J. N., male, aged thirty-two years, No. 23743, applied for treatment January 21, 1915.

History.—Previous health good up to two years ago. The present illness dates from that time, and first manifested itself by a tenderness in the upper portion of the sternum. The tender area became swollen about one year ago, and the axillary lymphatics became enlarged. Six months ago he discovered that his temperature became elevated every evening, at times reaching 103° and even 106°, though normal in the morning. During the past four months he has had dyspnœa and a cough, and has lost considerable weight. One month ago the tumor over the sternum was opened and drained.

Examination.—In addition to the open wound and swelling 3 inches in diameter over the sternum, the axillary and inguinal lymph-nodes are enlarged and the spleen is palpable below the lower border of the costal cartilages. The radiograph of the chest shows a shadow of large size (dimensions not given) in the thymus area of the mediastinum.

Following X-ray treatment the patient improved, the mediastinal mass decreased in size, and the patient was discharged.

He was readmitted March 14, 1916, again discharged, and readmitted January 2, 1917, having received during the whole period 56 X-ray treatments.

On February 9, 1917, no tumor was palpable in the axilla or over the sternum. The shadow in the upper mediastinum had decreased in size. His temperature was normal and he had gained 18 pounds in weight. He left the hospital against advice, and was readmitted March 28, 1917, having been without treatment in the interval. Examination then showed a recurrence of the mediastinal tumor associated with marked infiltration of the chest wall. The patient was very weak and his temperature rose to 103°–104° in the evenings.

He died May 7, 1917, of hemorrhage.

Microscopical examination by Dr. James Ewing of a piece removed for section from the tumor on the anterior surface of the chest shows the structure of giant-cell thymoma. The morphology resembles that of Hodgkin's granuloma, with excess of peculiar giant cells. The giant cells are large, rounded or polyhedral, with light-staining cytoplasm, nuclei multilobed and hyperchromatic, or multiple and vesicular and with very prominent strongly acidophile nucleoli. They are larger than the cells of Hodgkin's granuloma and somewhat resemble the myeloplaques of bone marrow. They are numerous and appear uniformly over the entire section. The derivation of the giant cells seems traceable to more numerous, smaller rounded or polyhedral epitheliod cells which make up the bulk of the tissue. In some areas the smaller cells are exclusively present while other portions consist chiefly of giant cells. Both frequently show mitosis. The stroma is composed of small arterioles and capillaries with cellular walls, along which the main tumor cells are often arranged as cubical or columnar epithelium. Throughout the section lymphocytes appear in moderate numbers. Necrosis appears in a few areas and also affects isolated giant cells.

CASE III.—F. S., aged eight years, male, No. 26223, applied for treatment February 6, 1919. Four months before this time the tonsils became enlarged. A tonsillectomy was performed December, 1918, after which the cervical lymph-nodes, which had already begun to increase in size, rapidly grew larger. An attempt was made to excise them in January, 1919.

Examination.—Poorly-nourished, pale child; cervical lymph-nodes much enlarged; some enlargement of the axillary nodes; inguinal glands not enlarged. Marked area of dullness over upper mediastinum. Heart displaced to left; otherwise normal. Abdomen: Spleen enlarged, its inner border within 2 cm. of the middle line and 3 cm. below the level of the umbilicus.

Blood examination shows the picture of lymphatic leucæmia. Red cells, 2,000,000; hæmoglobin, 50 per cent.; white cells, 143,000; small lymphocytes, 100 per cent.

Treatment.—February 13, 1919: 1436 mc., filtered through 2 mm. of lead, applied at a distance of 10 cm. over the spleen for nine and one-half hours.

The patient died suddenly the next day, presumably from the toxic effect of the products of a sudden excessive destruction of a tissue very sensitive to radium.

Autopsy, by Dr. James Ewing, showed a general lymphomatosis, affecting especially the thymus gland, the cervical, thoracic and abdominal lymph-nodes—hydrothorax, atalectasis. Lymphomatosis of spleen, liver and kidney.

Body of a male child, considerably emaciated. Two long scars on either side of the neck; large mass of lymph-nodes on left side; small mass on the right side. Axillary nodes moderately enlarged and very numerous. Recent effusion of blood in the subcutaneous tissue over the sternum. The left cervical nodes are fused into a soft affluent hemorrhagic mass, 4 x 5 cm. adherent to skin and tissue about trachea and œsophagus. The thymus region presents a soft tumor mass 6 x 8 cm., overlying and displacing the heart to left. The heart and pericardium are normal. Lymph-nodes at the root of the lung extremely enlarged. Left lung slightly compressed, and pleural cavity distended by clear fluid. Right lung congested and œdematous; no infiltration.

The spleen is moderately enlarged, firm; the section is pale, red, mottled. Malpighian bodies very prominent and enlarged. Liver slightly enlarged, firm. Section opaque, brownish-yellow, markings obliterated and no visible infiltration.

Stomach: Post-mortem digestion; slight hypertrophy of lymph follicles.

Kidneys much enlarged; both replaced almost entirely by a diffuse, opaque, soft tissue resembling leukæmic infiltration.

Intestines: Peyer's patches moderately enlarged.

Colon: Slight catarrhal colitis.

Bladder, prostate and testes normal.

Mesentery: Retroperitoneal nodes uniformly but slightly enlarged and soft.

Bone marrow: Hyperæmic and deep red.

There are diffuse extensions of the process into the left parietal pleura, the intercostal muscles, and infiltration of the periosteum of nearly all the ribs; and flat tumor masses extend outward from the spinal column to the mammary line over most of the pleura.

Microscopical Examination.—All affected organs are infiltrated by a small round cell, without much cytoplasm. In general, all cells are small.

Diagnosis.—Thymic lymphocytoma, lymphæmia.

CASE IV.—S. S., male, married, aged about twenty-five years, No. 26153. He applied for treatment January 10, 1919. His illness began four or five months ago with the development of a progressively increasing dyspnœa and pain in the chest and back.

Examination shows cyanosis and dilated veins over the chest and neck.

The physical examination shows the heart displaced to the left 2½ to 4 cm. from the middle line. Signs of fluid in the right chest are present below the angle of the scapula behind and the third rib in front. The upper part of the chest is dull to flat; below, perfectly flat. All over the right side and to a slight extent on the left, the breath sounds are loud, tubular, and whistling.

Liver is much enlarged and abdomen slightly distended.

X-ray examination of the chest shows the entire right side obscured by a dense shadow, which is undoubtedly due to fluid and obscures an underlying tumor mass.

Treatment.—January 11, 1919: 2030 mc., filtered through 2 mm. of lead, at a distance of 10 cm., for nine hours.

On January 10 the chest was aspirated.

The patient failed to improve. His dyspnœa increased, and he died on January 20, 1919.

Autopsy, by Dr. James Ewing, showed a thymic tumor; stenosis of the trachea; right hydrothorax; metastases to the lungs and liver; and retroperitoneal lymph-nodes.

The supraclavicular and axillary lymph-nodes are enlarged. The pleura over the diaphragm on the right side is the seat of firm, nodular masses, which are somewhat confluent. The lung is pressed under the clavicle, its lower border reaching to the fourth rib. A mass of tumor tissue firmly binds the lung to the chest wall.

The upper part of the mediastinum is occupied by a dense mass firmly adherent to the lung and pericardium. The pleura over the right lung is thickened and the seat of multiple nodules, in some regions an inch in thickness. The tumor mass in the mediastinum tightly encircles the trachea. The left lung is well aerated and almost normal.

Pericardium shows multiple nodules over its inner surface, especially prominent around the vessels. Small isolated nodules are present in the posterior mediastinum and within the right lung.

In the neck are many nodes extending upward along the spinal column almost to the pharynx.

Liver: The upper surface is studded with large and small tumor nodules. Spleen is normal.

The stomach posteriorly is firmly attached to a large retroperitoneal mass, to which are also bound the duodenum and both kidneys.

Microscopical Diagnosis.—The main tumor mass and all the metastases are composed of large round and polyhedral cells with densely staining nuclei. Since the main tumor involved the thymus, a diagnosis of thymic tumor is indicated.

CASE V.—W. F., male, twelve years of age, No. 29209. February 2, 1919.

History.—Aside from the usual diseases of childhood, the patient was well until December, 1918. He then, rather suddenly, developed pain in the chest, dyspnœa, and, later, cyanosis. These symptoms became gradually worse and a cough developed.

Examination.—Well-nourished child, with dusky mucous membrane and cyanotic skin; respiration labored. The whole of the left chest and upper mediastinum flat; fremitus increased; respiratory murmur absent; right chest percussion normal; breathing vesicular. Loud-blowing systolic murmur heard over the base, loudest over the second right space and transmitted to right. Over the centre of the sternum is a bluish, soft, discoid swelling 3 cm. in diameter. The axillary lymph-nodes on both sides are enlarged; cervical nodes are not enlarged. The abdomen is normal. X-ray examination of chest shows the left side almost entirely filled by a dense tumor

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mass, except at the extreme apex and along the lateral border of the ribs. A small amount of fluid is present in the lower left pleural cavity. The peribronchial glands around the left hilus are enlarged.

Treatment.—1500 mc. hours, filtered through 2 mm. of lead, were applied to the sternum at a distance of 10 cm. Improvement was apparent the next day. The dyspnœa cleared up, the venous congestion of the face, neck, and upper part of the chest disappeared; the tumor on the front of the chest completely retrogressed.

February 11, 1919: 103 mc. of active deposit of radium were administered intravenously. The injection did not produce further improvement; in fact, there gradually developed a recurrence of the dyspnœa. Between February 18 and March 4, 10 X-ray treatments were administered. These were distributed over the chest, back, axillæ, and supraclavicular regions.

February 15, 1919: 19 ounces of fluid were withdrawn from the left chest.

March 5, 1919: The father of the child decided to take the boy home and continue the treatment with X-rays at home. When he left he was improved, but not markedly so, and died at his home on March 26, 1919.

There can be no question but that this case is also a thymoma. The location of the shadow in the anterior mediastinum, the late involvement of the lymphatic glands—particularly the fact that the axillary lymphatics were first and most extensively involved—and the appearance of the tumor through the anterior chest wall, are all characteristic features.

CASE VI.—M. J., male, aged twenty-nine years, No. 24398, appeared for treatment December 7, 1917.

History.—Seven or eight months ago the patient noticed some swelling in the neck, which he attributed to an enlargement of the thyroid gland. At the same time dyspnœa developed which so increased up to five months ago that his condition became desperate. He was cyanotic and could not lie down. He was operated upon by his local physician, who removed what he considered a goitre. The mass was soft and found to contain pus—probably degenerated tumor tissue. Sections of tissue removed showed the structure of lymphosarcoma. A temporary improvement followed this operation, but two months later the former dyspnœa returned, but was relieved by four X-ray treatments over the chest. During the past three weeks there has been a gradual return of the dyspnœa.

Radiographic examination shows a wide mediastinal shadow, 17 cm. in diameter at the level of the manubrium, and 15 cm. wide at the level of the angles of the scapula. The heart and large vessels are obscured. The cervical lymphatic glands in the supraclavicular spaces of both sides are enlarged.

Treatment.—December 8, 1917: 1000 mc., filtered through 2 mm. of lead, applied over the sternum for eighteen hours, at a distance of 10 cm.

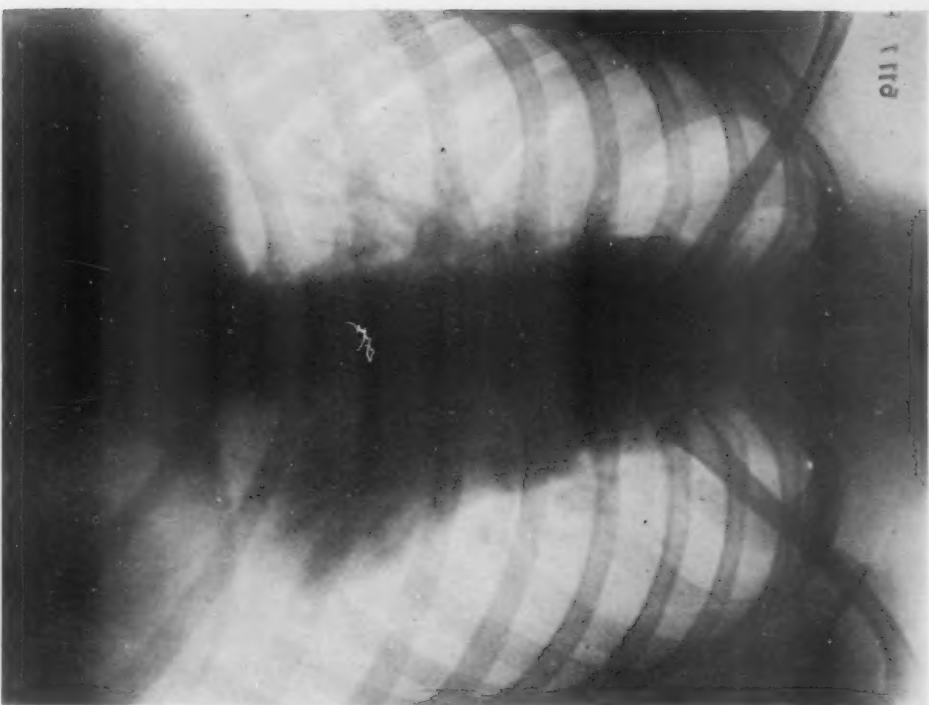Following this treatment the improvement was very great and

Fig. 1.—Röntgenogram of Case VII taken February 11, 1918, at the time the patient applied for treatment. The location and character of the tumor are typical of a growth of the thymus gland.
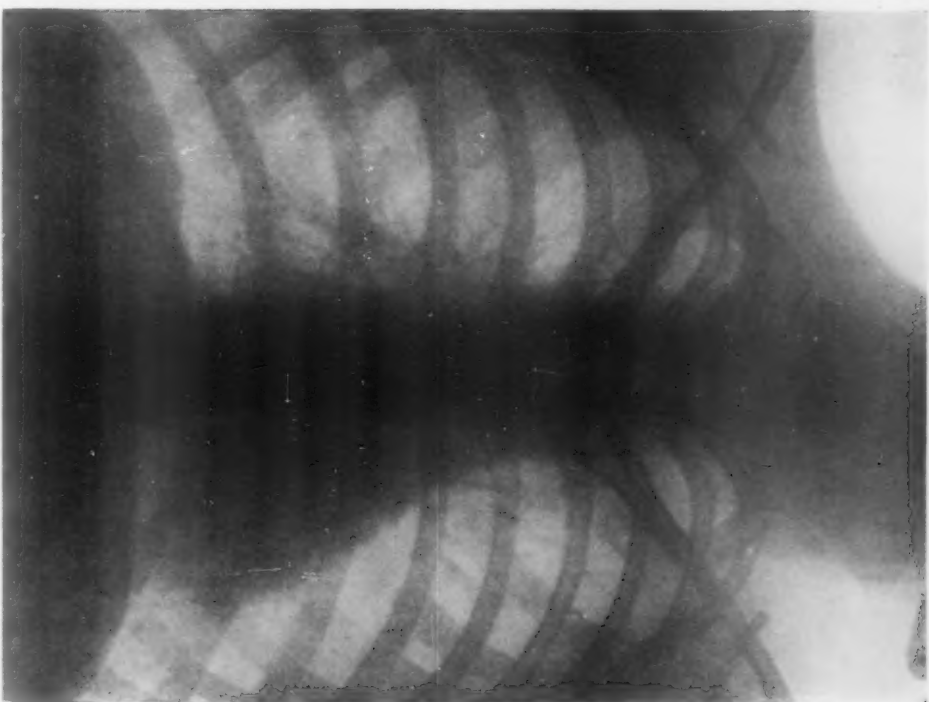

Fig. 2.—Röntgenogram of Case VII made October 22, 1918, showing disappearance of shadow of tumor.
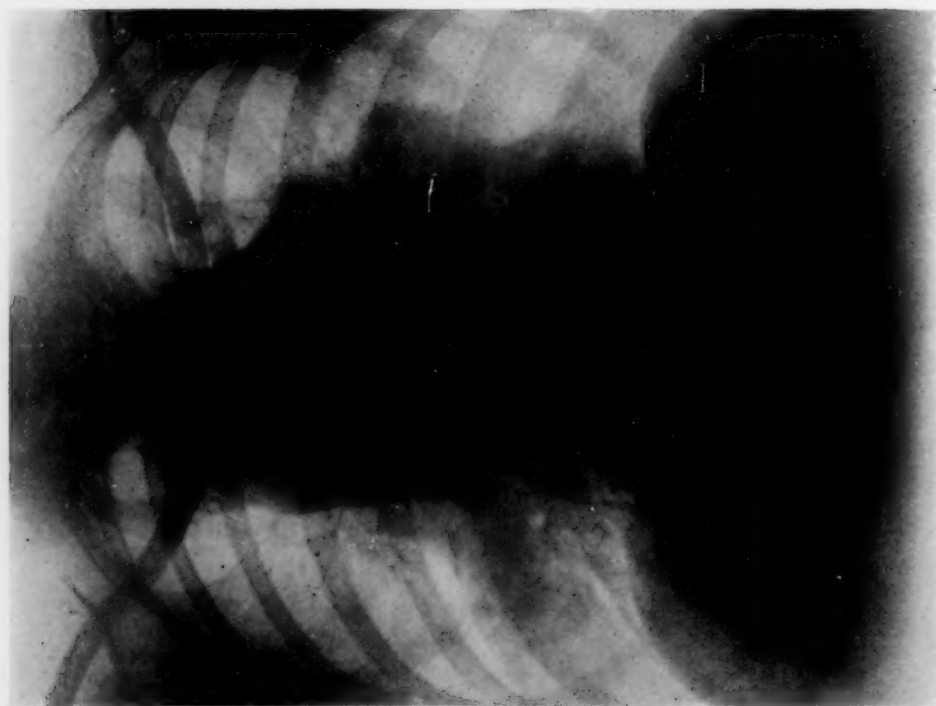
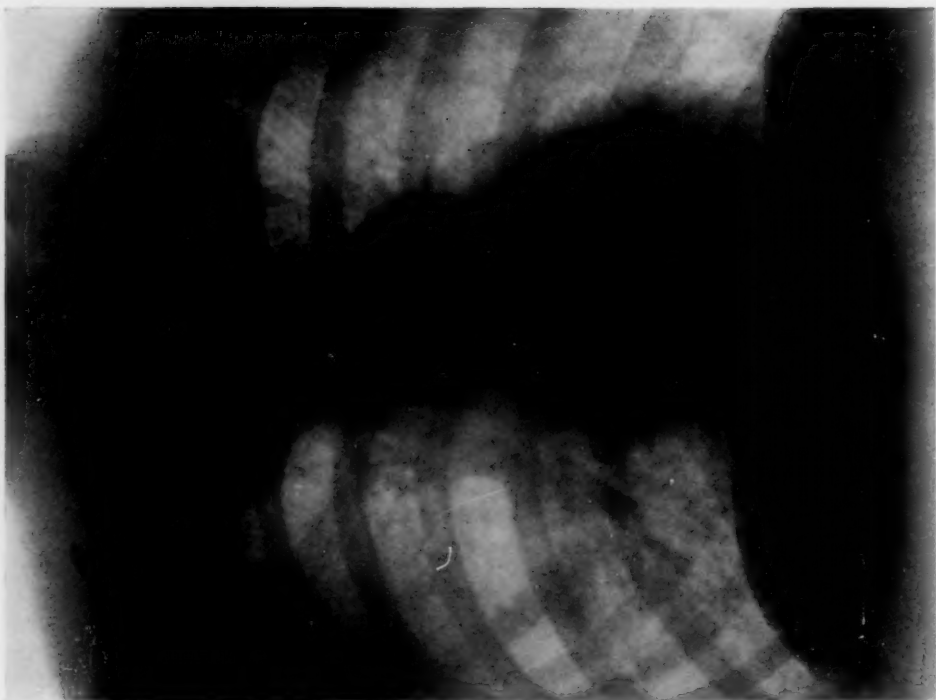FIG. 3.—Röntgenogram of Case VIII, June 12, 1918. Typical of thymus tumor.

FIG. 4.—Röntgenogram of Case VIII made May 8, 1919, showing improvement nearly one year after treatment.
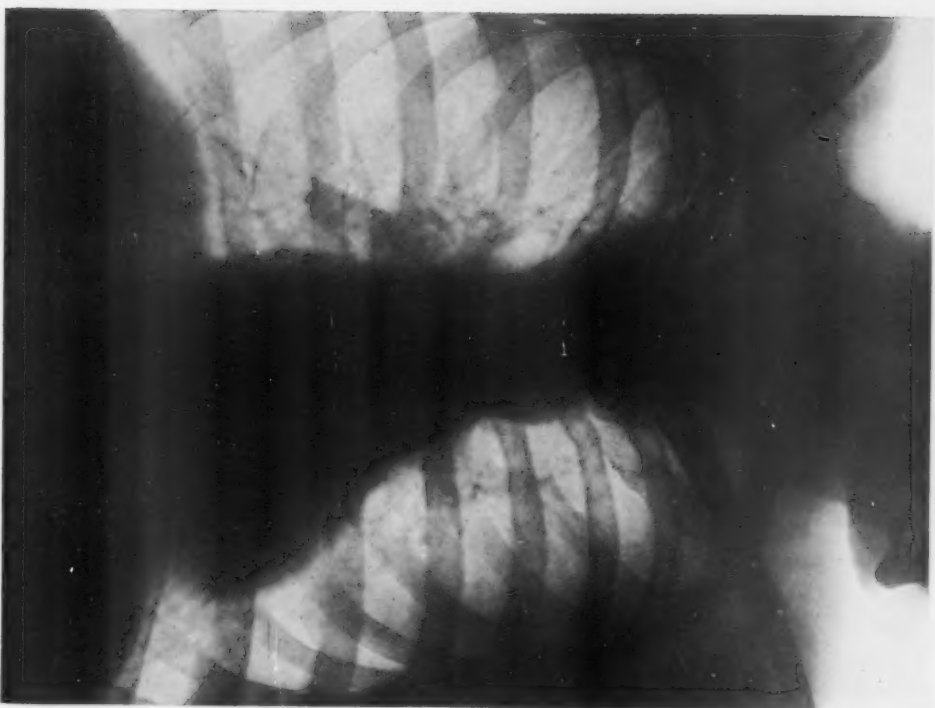
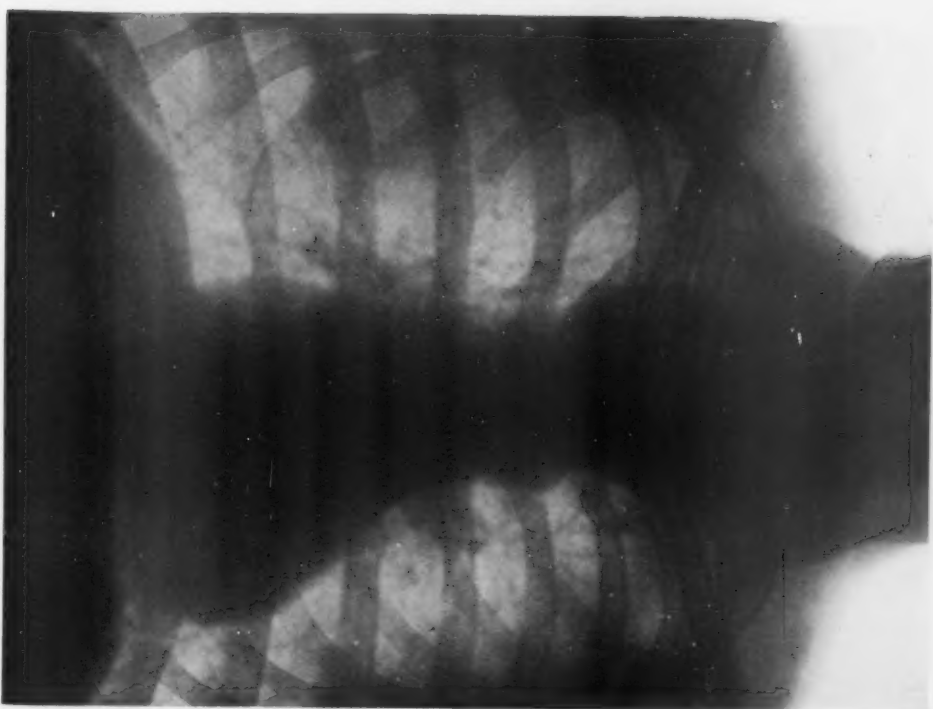FIG. 5.—Röntgenogram of Case IX on April 25, 1919, showing early thymus tumor.

FIG. 6.—Röntgenogram of Case IX, May 23, 1919, one month after treatment, showing very slight diminution of size and density of shadow.

treatment was continued January 20, 1918, when 1700 mc., filtered through 2 mm. of lead, were applied at a distance of 10 cm. for four and three-quarter hours. Further improvement followed and was described in a letter as follows by the röntgenologist who followed this case in Baltimore from whence the patient came for treatment: " The first röntgenogram made December 4, 1917, at St. Agnes Hospital, shows a single tumor shadow strongly suggestive of a lymphosarcoma occupying the centre of the chest cavity and extending well to both right and left sides. The blood-vessels and practically the entire heart are obscured by this shadow. A röntgenogram made December 17, 1917, after the first radium treatment, is clear cut, the heart is well defined, but in the region of the blood-vessels, especially at the arch, it is much wider than normal."

Röntgenograms made on January 23 and February 5, after the second radium treatment, reveal practically a normal chest picture with the exception of a very slight widening in the region of the ascending arch of the aorta.

Later we received a note stating that the patient died on March 13, 1919. It appears that death occurred suddenly and in some attack associated with high temperature, as if of some acute infection.

In this patient again the final proof that we are dealing with a primary malignant tumor of the thymus gland is wanting, the evidence being only clinical and depending upon the site of the growth.

CASE VII.—D. M., female, aged fourteen years, No. 25173, applied for admission February 1, 1918. She had suffered from attacks of " auto-intoxication " between the ages of six and ten. These attacks were severe between eight and ten years of age. Between ten and thirteen years of age her health was excellent. In the summer of 1917, while in the Adirondacks, she began to feel tired and developed an evening rise of temperature. She became so ill that she was kept in bed for two or three weeks and lost 15 pounds. At the same time she developed a cough and irregularity of heart action. After leaving bed, she attempted to go to school, and though somewhat better, she never regained strength or felt well during the whole of the next winter. About the middle of January, 1918, she noticed that there was some enlargement of the supraclavicular nodes on both sides.

She began treatment on February 2, 1918. At that time the deep cervical and supraclavicular lymphatic glands were slightly enlarged on both sides of the neck. The röntgen examination discloses a mediastinal mass at the level of the thymus (Fig. 1).

Treatment.—February 2, 1918: 5076 mc. hours, filtered through 2 mm. of lead, at a distance of 4 cm., applied over the upper portion of the sternum.

Between February 4 and June 6, 1918, she received 15 X-ray treatments distributed over both sides of the neck, both supraclavicular regions, and both axillæ.

Subsequent course: March 7, 1918, X-ray examination showed that the mediastinal mass had diminished 2 cm. in diameter.

March 30, 1918: Further reduction in the mediastinal mass. Her health had improved much and the cough was less.

June 12, 1918: General health good; no cough; no glands palpable on the right side of the neck; only pea-sized nodules on the left side, and continued reduction of the mediastinal mass; 727 mc., filtered through 2 mm. of lead, applied at a distance of 4 cm., over the upper part of the sternum for seven hours.

September 9, 1918: 1736 mc., filtered through 2 mm. of lead, applied over the upper part of the sternum at a distance of 4 cm. for two and nine-tenths hours.

Following this date the conditions in the mediastinum remained unchanged.

May 5, 1919: The general health of the girl had remained excellent, and X-ray examinations gave no evidence of a recurrence of the mediastinal growth (Fig. 2).

Case VIII.—G. K., male, aged twenty years, No. 25565, applied for treatment June 15, 1918.

History.—Aside from pneumonia four years ago his previous health had been good. His illness began with the development of a cold accompanied with cough in October, 1917. During the next month or two this alternately improved and became worse. In February, 1918, he developed pneumonia with which he was ill in bed for four weeks. His physician believed that he had tuberculosis and a little later referred him to Doctor Trudeau's sanitarium, where he remained eight weeks until June 1. When he went there he had a cough with mucous expectoration, but no blood; severe pain in the left side of the chest, and some pain in the right chest. At the time he left the cough had ceased and the pain had disappeared. He had also gained in weight from 114 pounds to 130 at the time of leaving. On his return to New York he was referred to us for radium treatment, solely because the X-ray examination of his chest showed the presence of a mediastinal mass.

The röntgenological examination at the Memorial Hospital on June 22, 1918, showed a large well-defined mediastinal mass (Fig. 3). Its upper limit extended to the level of the clavicles. The lower border was on a level with the second rib. The shadow of the tumor measured 12 cm. in diameter.

On the right side the mass extends outward beyond the right border of the heart, and from the right hilus an infiltrating process extends into the right middle lobe of the lung, the upper border of which is sharply defined. There is one discrete large gland at the left hilus.

The patient has the general appearance of a fairly well-developed young man who is not very well nourished and who looks ill. The heart is normal and the abdomen is normal.

Treatment.—June 16, 1918: 919 mc., filtered through 2 mm. of lead, applied over the upper part of the sternum at a distance of 10 cm. for twenty-two hours.

Between June 18 and 22 he received five X-ray treatments. Examination June 22, 1918, shows definite improvement.

July 1, 1918: Marked diminution in the size of the mediastinal mass.

May 15, 1919: The general health of the boy had remained good and an X-ray examination gave no evidence of a recurrence of the growth (Fig. 4).

CASE IX.—A. W., male, No. 26424, applied for treatment April 27, 1919. Previous health good. During the past summer developed a dry cough and some slight dyspnœa on exertion.

Physical examination disclosed a normal chest except for dullness over the upper mediastinum.

The general appearance of the patient is that of a well-developed and healthy man. Radiographic examination of the chest shows a flattened spherical mass 9½ cm. in diameter lying immediately behind the upper end of the sternum with its centre opposite the sternal notch. Its location is typical of thymus tumor (Fig. 5).

Treatment.—April 27, 1919: 1058 mc., filtered through 2 cm. of lead, and applied at a distance of 10 cm. for eighteen and one-half hours over the upper anterior mediastinum.

May 24, 1919: Second radiograph shows a very slight decrease in the diameter and density of the tumor (Fig. 6). The general condition of the patient is improved, while the location of the röntgenographic shadow of this tumor is typical of tumor of the thymus gland. The failure of the growth to respond more to the radium treatment indicates that tumor is different from the type of lymphosarcoma present in the other cases.

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MALIGNANT DISEASE OF THE LUNGS, ITS EARLY RECOGNITION AND PROGRESSIVE DEVELOPMENT, AS STUDIED BY THE RÖNTGEN RAYS, WITH REMARKS ON TREATMENT *

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Preceding the study of the chest by means of the röntgen rays, an antemortem diagnosis of malignant disease of the lungs, according to Warfield, was not made in a large percentage of cases because of the general good condition of the patients and the indefinite symptoms which this disease produces. Even with the study of the chest by means of the röntgen rays, I am sure that the disease is not generally recognized in its earliest stages. In its earliest stages I believe that it cannot be definitely diagnosed by any means. In its latest stages it should not be mistaken by any röntgenologist. By reviewing the röntgenograms of a large number of patients, some of which have been followed over a period of several years, during which we have studied the progressive changes in the lesions, and by reversing the study, we have been able to trace the gross lesions back to their very incipiency. As a result, I am hoping that we shall be able to recognize this disease much earlier than it has ever been recognized heretofore. There is, of course, a microscopical stage in its development at which time we can never hope to recognize the disease.

Its early recognition will serve as a guide in the treatment. In some instances it will prevent a mutilating operation, and I am hoping in the future that its early recognition may lead to the early institution of some form of constitutional treatment which is, as yet, undiscovered. I am sure that at present many patients are operated upon with the hope of complete recovery at a time when there is already distinct metastasis in the lungs and mediastinum. On this account I believe that we should urge a röntgen examination preceding all operations for carcinoma of the breast. When the lesions within the chest are doubtful, I believe that they should not stand in the way of an operation.

Malignant disease of the lungs may be divided into *primary* and *secondary* (or metastatic).

Primary malignant disease of the lung is rare. It is of two types: the nodular and the infiltrating. The nodular type consists of nodules developing near the roots of the lung, but also in the parenchyma, and consists of varying sized masses, rather sharply defined and irregularly outlined. The infiltrating type, which is the more common, begins at the root of the lung and gradually infiltrates the entire lung. This fills the entire chest, and may come on so gradually, and produce such indefinite

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symptoms, that the disease is not suspected until the entire lung has become filled, and until one side of the chest is entirely solid, associated with marked displacement of the heart and mediastinal tissues to the opposite side, and associated with the formation of pleural effusions early.

The symptoms associated with primary malignant disease of the lungs consist usually of dyspnœa, pain, with or without pleuritic friction, and dullness varying with the degree of the involvement of the lung. As a result of the extensive dullness, the first thought is a pleural effusion, but in aspirating the chest only a relatively small amount of fluid is obtained, and this is generally a bloody serum. When bloody serum is obtained in a relatively small amount, malignant disease should always be suspected, and a röntgen examination should be made if it has not been made previously. By means of the röntgen rays, one recognizes an opacity in the early stages consisting of a mass of infiltrating dense tissues about the root of the lung spreading towards the periphery. If the malignant disease is sarcoma, it is especially apt to extend outward along the septum between the upper and middle lobe, or between the upper and lower lobe on the left side, or about the middle lobe on the right side, and this may be a fairly early sign. If the primary malignant disease is carcinoma, it consists of an infiltrating mass about the root of the lung extending outward along the bronchial tree, I believe most frequently in an upward direction, which serves somewhat to distinguish it from the inflammatory infiltrations about the root of the lung which tend to spread downward. In the late stages the whole of one side of the chest is a uniform dense mass with displacement of the heart and mediastinal tissues to the opposite side, with generally clear lung on the opposite side. The lung area on the opposite side may be reduced to one-third or less. In less advanced stages the apex of the lung may remain clear and the lower portion of the base of the lung may remain clear, unless there is associated pleuritic effusion. Sometimes by varying the position of the patient this lower portion of the base of the lung can be demonstrated to be clear by displacement of the fluid upwards.

Secondary or metastatic malignant disease of the lung is very common, and I believe much more common than has been recognized up to the present time. In a quotation made by Warfield in the report of cases studied in Middlesex Hospital, he states that metastases were found in the lungs of 178 out of 516 autopsies performed on persons who had died from cancer of the breast, and he states that at least one-third of all patients dying from cancer of the breast have metastasis in the lungs. It would seem to me, from my studies, that the proportion would be even higher than this. Gross found in 432 autopsies, collected from various sources, metastases in the lungs in 49.9 per cent.

Metastatic sarcoma, in my experience, has mostly followed sarcoma (?) of the testicles, though it may, of course, be secondary to sarcoma anywhere in the body. The lesions are nodular and occupy more particularly

the parenchyma of the lungs. They are generally sharply defined and vary in size from a small pea to an English walnut, or rarely as large as an orange. They are probably carried to the lungs in the blood stream and are distributed as emboli in the terminal blood-vessels in the parenchyma. In none of these cases studied by me did the patients have any lung symptoms, and the disease in the lungs had not been suspected by the physicians who referred the patients—generally for treatment of some local recurrence or some other metastasis. This condition of metastatic sarcoma of the lungs occurs so frequently, in my experience, that I never start treatment of a sarcoma without examining the chest, and when metastatic sarcoma of this kind is found within the chest, the röntgen treatment has been of no avail.

Hypernephroma metastasizes early to the lungs, and I believe the chest should be examined in every case in which hypernephroma is suspected, or whenever hypernephroma has been diagnosed. In one case sent to me for post-operative treatment three weeks after the operation for hypernephroma, in which the patient's general condition was good and there was no thought on the part of others as to recurrence or metastasis, I made an examination of the chest and found undoubted evidence of infiltration of the lungs. This consisted, not of nodules, but of a general infiltration of small miliary bodies extending outwards from the roots of the lungs which somewhat resembled an infiltrating tuberculosis, but the lesions were more sharply defined and did not follow the usual distribution of tuberculosis. The appearances were sufficient to make a diagnosis when associated with the history, and the subsequent development of the case proved that my diagnosis was correct. I am not sure that this diagnosis could have been made from the plates without the previous history.

Metastatic carcinoma of the lungs, in my experience, has most frequently followed carcinoma of the breast. However, it must be admitted that I have had very much more opportunity of studying this group of cases than those belonging to malignant disease in any other part of the body. I have studied the chests in 225 cases of malignant disease of the breast. At present I make a chest examination of every patient referred to me for röntgentherapy for carcinoma of the breast, whether for the primary disease, ante-operative, or post-operative treatment. There have been long intervals in the past when I did not follow this procedure. My experience now convinces me that this should always be done. Metastatic carcinoma of the lung is of four types:

1. The *nodular type,* which we all have recognized for many years, and which is characteristic as early as the nodules can be demonstrated. These nodules are generally distributed in the parenchyma of the lungs, though they may be located about the roots as well as in the parenchyma. These nodular lesions vary in size from that of a pin-head to an English walnut. They are generally not very dense and are not sharply out-

lined, but present a fuzzy appearance suggesting cotton balls. They are very much less dense and less sharply defined than metastatic sarcoma, though their distribution is very similar. This is the type that has been particularly studied and described by Moore and Carman. Apparently no other type was recognized by them at the time of the complete and able presentation of this subject before the American Röntgen Ray Society in September, 1915. They describe the lesions as varying in density from a faint shading to a degree approximately that of the heart, depending on the stage of the disease. At the time of the presentation of this paper it was undoubtedly the most complete röntgenological study of this disease made up to that time, and in general represents our knowledge of the subject up to that date. They had made a study of 71 cases. The character of the distribution of these lesions would lead one to suspect, as Moore and Garman also suggest, that these metastases are embolic and travel through the blood rather than through the lymph streams.

2. The *infiltrating type, beginning at the hilus or mediastinum*. This, I believe, is the most common type and, as has been so well said by Holmes and Ruggles, is " unrecognizable in the early stages and unmistakable in the later ones." This begins as a general thickening or infiltration about the hilus which, in its earliest stages, resembles the inflammatory thickenings that we so commonly find in this region, but which I believe differs slightly in that it presents more localized density without outline at the very roots of the lungs. It then shades so gradually as it extends outwards that it is lost in outline. I think I notice, too, a greater tendency towards an extension upward about the upper bronchial tree and toward the upper lobe than is usually found in the inflammatory lesions, for, as we know, in the chronic inflammatory lesions giving rise to thickening about the hilus of the lungs, there is a tendency towards increased thickening about the lower bronchial trees as compared with the upper. This evidence, however, in this early stage is only suggestive, and is not characteristic. As the disease progresses this area of density increases, extending toward the periphery, but extending particularly toward the upper lobe. Associated with this there is a general increase in the width and density of the mediastinal tissues. In some cases this mediastinal thickening is greatest in the upper portion just below the inner extremities of the clavicles, and at times distinct masses can be recognized in this upper mediastinum. It would seem, from the location and general distribution and development of the disease in these cases, that it is a direct extension through the lymphatic system, just as it commonly extends through the palpable glandular system into the axilla, then into the supraclavicular region, and then into the mediastinum. Handley concludes that the vast majority of metastases are due to lymphatic permeation. It has seemed to me that, in some cases, I have been able to transform these lesions into dense fibrous tissue and, in a few cases, the patients are still living after several years. One patient is living nine

years after removal of both breasts for malignant disease, and eight years after definite mediastinal involvement. She has been treated by röntgentherapy and looks well.

3. The *miliary infiltration* (very similar to miliary tuberculosis), and consists of a fine mottling throughout the lung fields, but, as recognized also by Holmes and Ruggles, these small areas of increased density are a little larger, more dense, and more sharply outlined than those of tuberculosis. This type is more difficult to diagnose, I believe, than any of the others, and it is likely that the diagnosis could not be made excepting in association with the history and careful study of the clinical symptoms. The absence of fever and the absence of other symptoms of miliary tuberculosis will easily eliminate tuberculosis in the differential diagnosis. An infiltrating syphilitic lesion of the lungs may resemble it, but can be differentiated by means of a negative Wassermann test. Infiltration of the lungs associated with leucæmia also resembles this form of metastatic carcinoma, but a careful differential blood examination will eliminate the diagnosis of leucæmia.

4. This type consists in a *progressive thickening of the pleura* associated with pleural effusion. This type is probably a direct extension of the disease from the breast into the pleura. Deaver and McFarland say that in " advanced cases the intercostal muscles often become diseased, and in some instances the pleura is involved as a result of the extension of the cancer cells through one or other of the intercostal spaces." Handley found secondary nodules in the pleura in 38 per cent. of 422 cases.

It would seem, from the above types, that all the various theories as to the nature of the extension of metastatic carcinoma are clearly illustrated and that all the theories are correct in certain cases.

In a series of cases studied previous to July 1, 1919, consisting of 242 cases of carcinoma, we found positive evidence of pulmonary carcinoma in 216; negative, 29; doubtful, 7. This high percentage of positive findings is partially influenced by the fact that, in many instances, the examinations were made because disease was actually suspected in the chest, but it also indicates the advanced stages of the disease in which the majority of patients are referred for röntgentherapy.

Of the 216 cases of malignant disease of the lungs there were: Primary carcinoma, 2; metastatic carcinoma, 196; primary sarcoma, 7; metastatic sarcoma, 11.

Of the cases of metastatic carcinoma of the lungs the great majority were secondary to carcinoma of the breast. I am not specifying the number because it would give a wrong impression, since all patients suffering from carcinoma have not been examined. Of the cases of metastatic carcinoma of the lungs there were: Mediastinal and hilus involvement, 150; nodular, 34; miliary, 10; pleural, 12.

It is evident, therefore, that the mediastinal and hilus cases are almost five times as frequent as the nodular.

The statement has been made that fat patients are more liable to early and rapid metastasis than thin patients. I, therefore, studied the various groups as above arranged, with the idea of determining whether any of these groups were especially liable because of the amount of adipose tissue. Also to confirm or deny, if possible, the above statement as to the relation of fat and metastasis.

Of the mediastinal and hilus variety there were fat patients, 53; medium, 65; thin, 32. Nodular variety, fat, 5; medium, 17; thin, 12. Miliary, fat, 6; medium, 4; thin, none. Pleural, fat, 4; medium, 5; thin, 3.

It would seem, therefore, that the thin patients are slightly more liable to the nodular variety of metastatic carcinoma, and second that the fat and medium patients are very much more liable to metastasis than the thin.

In a series of 42 cases studied since July 1, 1919, in each series all patients who were sent for post-operative treatment following carcinoma of the breast were examined, and we found positive metastatic carcinoma, 17; doubtful carcinoma, 16; negative, 9.

It would seem, from these studies, that approximately 50 per cent. of the cases that come for post-operative treatment have metastatic carcinoma within the chest at that time. The effect of röntgentherapy on these pulmonary lesions is difficult to determine. One does not generally have the opportunity of studying these patients over a long period of time unless they are under some form of treatment. Therefore, we do not have the opportunity of comparing the progressive changes in a group of untreated cases with the changes that I can recognize in the patients which have been treated. In some of these patients treated some of the lesions seemed to have disappeared temporarily. In others, the lesions become more dense and more fibrous, resembling somewhat a fibroid phthisis. In a few instances the patients are still living several years after beginning treatment, and are apparently in good health. In most cases, however, while there is temporary improvement extending over a period of months or a year, the disease takes on a more rapid form of development with evidence of general carcinomatosis followed by death. The symptoms and röntgen findings which develop as a result of progression of the disease most frequently involve the spinal bones, but also frequently involve the upper extremities of the humeri and the upper extremities of the femurs. The liver, in the cases which I have had under treatment, has not become involved, as indicated by symptoms of enlargement, as frequently as one would suspect from the text-book statements.

Röntgentherapy in these cases does accomplish some good, and, in a number of cases, definite disappearance of lesions has been proven. One patient was referred to me by the late Dr. Wm. L. Rodman, who had one breast amputated and found to be sarcoma, and the other breast amputated a year later and found to be carcinoma, and then, within six months she was referred to me with a very definite mediastinal tumor, and this

was nine years ago. She is to-day in reasonably good health, is very stout, and X-ray examination shows partial calcification of this tumor. In some other patients I have found disappearance of the metastatic nodules in the lungs, and in others disappearance of the mediastinal involvement. In five patients I have been able to get a healing process in metastatic carcinoma of the spine. I have been able to get reformation of portions of ribs that had been destroyed by metastatic carcinoma, or at least in which the lime salts had all been removed, so that the outline of the rib could not be seen at the area of disease. These have reformed. Such results are only obtained occasionally, however. I believe that all cases can have their lives prolonged and perhaps made more comfortable.

In general, I believe that when the lungs are involved it must be looked upon as a part of a general carcinomatosis, and with few, if any, exceptions one cannot expect a complete and permanent recovery.

CONCLUSIONS

1. Primary malignant diseases of the lung is rare, but presents rather characteristic appearances röntgenographically.

2. Metastatic malignant disease of the lung is common, and should always be looked for in connection with advanced malignant disease.

3. A röntgen examination of the chest should be made in every case of carcinoma of the breast referred for operation or röntgentherapy.

4. Metastatic carcinoma of the lungs may be one of four types: Nodular, mediastinal with infiltration about the roots, general, miliary infiltration, or pleuritic.

5. Greater attention to details in these studies will lead to earlier recognition of the disease.

6. Röntgentherapy can be expected to prolong life and give some improvement in symptoms, and perhaps occasionally the life may be prolonged sufficiently to consider it a cure.

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CIRCUMSCRIBED PAN-MURAL ULCERATIVE CYSTITIS*

ELUSIVE ULCER (HUNNER)

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In 1914 Hunner presented his first report of eight cases of a rare type of bladder ulcer in women (Hunner, G. L.: *Tr. South. Surg. and Gynec. Assoc.*, 1914, 27; *Boston Med. and Surg. Jour.*, 1915, 172, 660). He has subsequently reported seventeen additional cases under the title of " Elusive Ulcer of the Bladder " (Hunner, G. L.: 1918, *Amer. Jour. of Obstet. and Diseases of Women and Children,* lxxviii, No. 3). During the past three years, ten such cases have been treated on Dr. John G. Clark's service at the University Hospital and this paper is based upon our findings in these patients.

While this type of lesion is undoubtedly rare, we are confident that it is often overlooked not only because of failure to make a careful inspection of every portion of the bladder, but also to lack of proper interpretation of the findings which in the earlier cases may show very little variation from the normal so far as gross changes are concerned. In looking back over our own experience in cystoscopic work, we recall cases that were doubtless of this type, in which the condition was overlooked completely, or, recognizing it, we failed to direct appropriate treatment for its cure.

This error was forcibly impressed upon us by a case, long under our care, who finally consulted and was operated upon by Doctor Hunner; at operation he demonstrated, without question, the extent of disease and the complete cure in this case left no doubt as to the wisdom of his teaching regarding the value of excision.

Hunner has described the condition under the name of " Elusive Ulcer," choosing the term to designate the difficulty often experienced in locating the ulcer. Such a nomenclature seems unsatisfactory in that it gives no conception of the pathology and, in fact, may be misleading in that it magnifies the importance of the ulcer which in reality is a small part and but an end result of an inflammation involving a considerable portion of the entire bladder wall. The lesion brings to mind a type of disease which Nitze calls Cystitis Parenchymatosa (Knorr: *Die Cystoskopie und Urethroskopie beim Weibe,* p. 211), in which not only the mucosa but the submucosa and muscularis participate, and until recently we have spoken of the lesion we are about to describe as a circumscribed parenchymatous ulcerative cystitis. Dr. Allen J. Smith has suggested

that the word " pan-mural " be substituted for " parenchymatous," pointing out the fact that the former is more accurate in its application to the pathology of the bladder as well as more descriptive of the extent of the inflammation, and we have followed his suggestion.

Pathology.[1]—Grossly, the lesion is characterized by more or less thickening of the entire bladder wall with œdema and minute, superficial ulceration of the mucosa. The disease is practically always limited to the vertex of the bladder, although rarely it may extend downward and laterally on one or both sides to within a few centimetres of the trigone. The amount of bladder wall involved varies considerably; of our operative cases, the tissue removed ranged from 2 by 3 centimetres to 7 by 7 centimetres. The disease is never " patchy " in distribution, but is limited to one section of the bladder. The bladder wall is distinctly firmer than normal and in two of our cases the induration could be detected on bimanual examination. The inflammation may extend beyond the bladder confines, not infrequently involving the paravesical tissues and adjacent peritoneum. Such a paracystitis is most commonly found in association with and in the immediate vicinity of a comparatively large ulcer.

The mucosa is thickened and œdematous and with proper illumination the diseased area stands out in sharp contrast with the normal bladder. The ulcers may be single or multiple; in our series the latter has occurred more commonly, but in no case have we found more than three. The areas of ulceration are always minute and very superficial; because of this one may at first glance have difficulty in locating them. The ulcer usually presents a clean, bright red surface with sharply cut edges. The lightest touch with a cotton-covered probe will be followed immediately by bleeding.

Microscopically, the picture is that of an inflammation involving the entire bladder wall and paravesical tissues. The bladder wall is thickened, due in small part to fibrous tissue, but largely to loosening of the intermuscular and paravesical connective tissue incident to œdema. Within the areas of ulceration, the inner surface of the mucosa fails to show the presence of the ordinary epithelium; the basement membrane is, as a rule, well marked and is often somewhat thickened. Immediately beneath the basement membrane in the non-ulcerated portions are areas of dense round-cell infiltration, consisting mainly of lymphocytes and plasma cells. Where there is loss of the surface epithelium, the fibrous tissue is very loose and is filled with polymorphonuclear leucocytes.

The deeper part of the submucosa may be fairly free from an inflammatory exudate and shows little change save loosening from œdema, but its blood-vessels often stand out prominently, due to the number of polymorphonuclear leucocytes which are seen not only within the lumen,
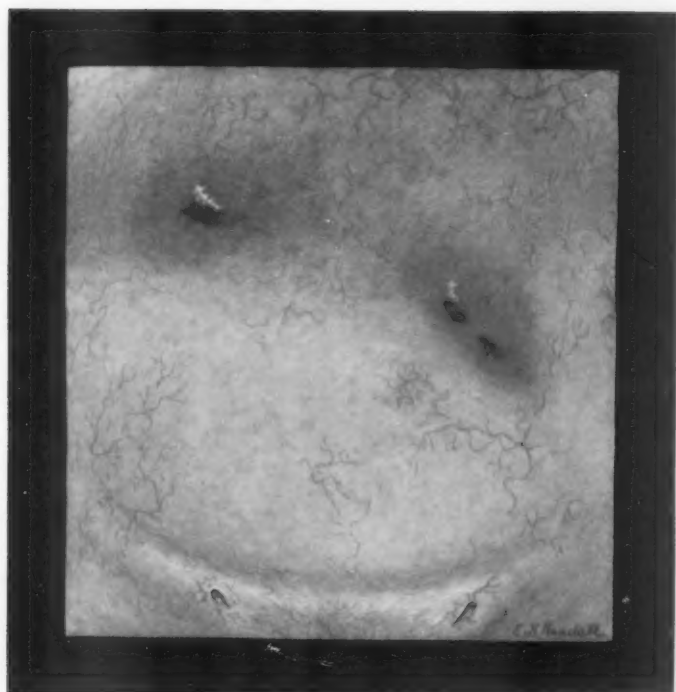

Fig. 1.—Cystoscopic picture showing diseased area above and normal mucosa with ureteral orifices below. Intense congestion about three small, superficial ulcers which are situated in lower portions of the œdematous zone. Section excised measured 7 x 7 x 4 cm. The disease was located in the vertex of the bladder, but is here shown near the base in order to demonstrate the essential features in one drawing.
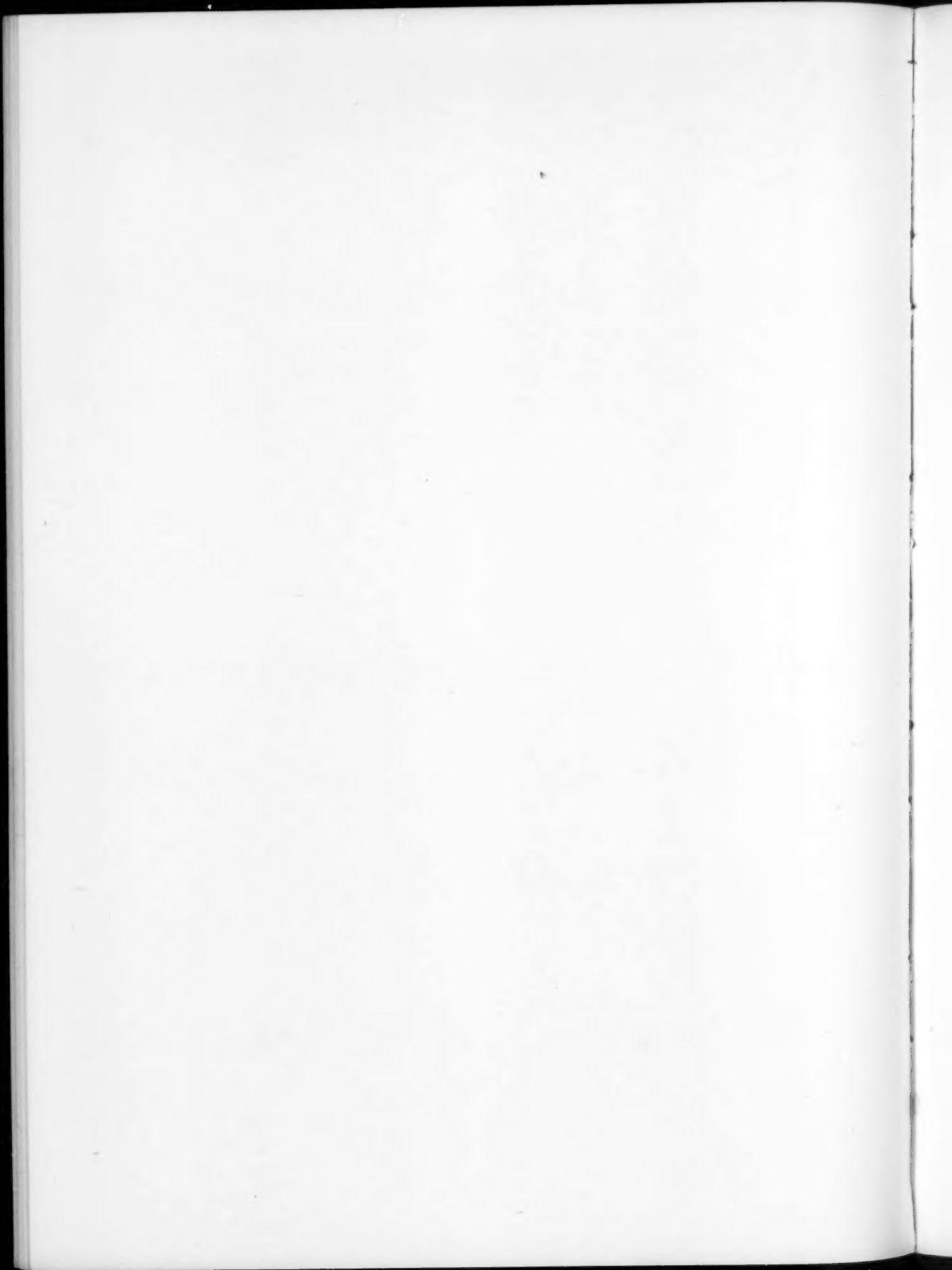
but infiltrating the vessel walls and perivascular tissues. Here mononuclear cells are fairly rare, only an occasional large mononuclear being seen.

The same vascular and perivascular polynuclear invasion affects the blood-vessels in the muscular and outer coat, being often very marked in the latter, so that a leucocytic thrombus is in many instances apparent, and the leucocytic involvement of the coats is such that one would speak of an acute exudative arteritis and phlebitis. The appearance is given that the lymph channels are similarly affected. Foci of round-cell infiltration likewise occur in the muscle fascicles, but no degenerative changes have been observed.

Cystoscopic Picture.—The picture presented by the cystoscope (Fig. 1) is fairly typical in most cases, and having seen one or more, the observer is immediately aware of the fact that he is in all probability dealing with an ulcer-bearing area. The most striking feature is œdema of the mucosa, localized in the vertex of the bladder. The œdematous area is somewhat hazy, there is an absence of sharp definition of the vessels, or the vessels may appear unduly short, seeming to suddenly appear in the field, and after a short distance, completely disappear from view. Or they may be seen in small clusters, giving a " flea-bite " appearance in one or more areas.

The mucosa has lost its normal golden-white, glistening surface, and has assumed a more or less diffuse, dull pink color. Occasionally one sees elongated, elevated areas of mucosa which give the appearance of scar tissue, and in one of our cases two small ulcers were mounted at the summit of such an area. With a well distended bladder and good illumination, one can make out very clearly the sharp line of demarcation between the normal and œdematous mucosa.

The ulcers give the appearance of minute areas of healthy granulation tissue, the base being a deep red color and rarely covered with fibrin. Through the cystoscope the ulcers stand out even more plainly than with the naked eye; they present sharply cut edges and are always superficial, appearing as if minute areas of mucosa had been removed with a sharp curette. They are always small, varying in our cases from 1 by 2 mm. to 4 by 5 mm. Surrounding the larger ulcers is an area of intense congestion and œdema which the smaller ulcers often lack. As has been our experience in two cases, the ulcers may show active bleeding. Touching the ulcer with a catheter or probe at once produces bleeding, and the patient will complain of sharp pain. The bladder base, including the trigone and ureteral orifices, is always normal in appearance; not uncommonly, as the result of frequent urination, papillary hypertrophy of the internal sphincter is present.

Symptoms.—An analysis of the symptoms presented by our patients gives one common to all—bladder pain with intense urgency and frequency of urination. In the most severe cases the bladder must be emptied every few minutes, with pain during, but more especially after,

urination. Often the dysuria is exaggerated at night, but the reverse may be true. There is an associated intense urgency, so that the patient finds it next to impossible to hold the urine. Not infrequently the pain is located in the lower abdomen, usually just above the symphysis on one or both sides of the median line. This is doubtless due to an extension of the inflammation to the peritoneum and the pain may closely simulate that of a chronic pelvic peritonitis or appendicitis. The pain may be localized to the bladder and lower abdomen or may be referred; in one of our cases intense rectal discomfort was complained of, in another a sensation of " spasm " in the perineal region, and Hunner calls attention to the frequency of referred pain in one or both hips, depending on the location of the ulcer. The severity of symptoms, of course, varies in different patients, and in several instances we have noted more or less of a periodicity of exacerbations and remissions, lasting several weeks and entirely independent of treatment. That this is not due to healing of the ulcers is evident from the fact that the remission occurs with no apparent change in the appearance of the bladder. As is so frequently the case in inflammation of the bladder, premenstrual congestion exaggerates the symptoms. The symptomatology is usually one of long standing; in our series the duration varied from six months to fourteen years, and the average is about four years.

As the result of years of bladder trouble, these patients have been under more or less constant medical attention and are consequently well versed in their urinary findings. As a rule, they report that the urine was found to be normal, but in two of our cases a history of hæmaturia was given. The bleeding is of short duration, lasting only a day or so, and then completely disappears, at least on gross examination.

Microscopic examination of the urine may be normal with the exception of a slight excess of leucocytes and a few red blood-corpuscles. In only two of our cases were many leucocytes reported. One case came to us with macroscopic hæmaturia which was found to originate in a small ulcer, two others showed a few red blood-cells in the centrifuged specimen, while the remainder showed none. A grossly normal appearing urine with the presence of a few leucocytes and red blood-cells may be said to be characteristic of the majority of these cases.

Etiology.—We are at a loss thus far to explain the cause of this condition, but believe with Hunner that it is due to an infection, probably hæmatogenous in origin. The tubercle bacillus is certainly not responsible. In no case has it been demonstrated microscopically nor by guinea-pig inoculation; nor is there anything in the cystoscopic picture or the sections of the bladder suggesting tuberculosis. Hunner seems inclined to ascribe the inflammation to an infection secondary to such a focus as tonsils, teeth, or sinuses; we have made it a special point to determine this possible etiology, but without success. In two of our cases the patients date the onset of symptoms from repeated catheterization, one

FIG. 2.—Section of bladder wall, showing ulcer at A. Numerous areas of round-cell infiltration in submucosa. Œdema shown by looseness of muscularis. Only slight increase in connective tissue.
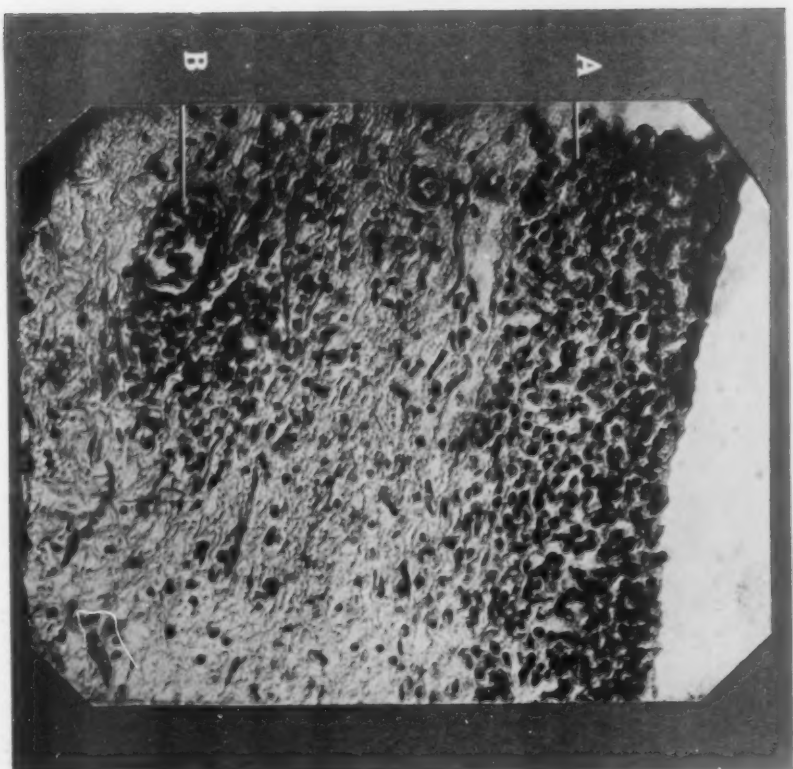

FIG. 3.—A. Mucosa in non-ulcerated area. Infiltration of round cells composed almost entirely of lymphocytes and plasma cells. B. Blood-vessels in submucosa filled with polymorphonuclear leucocytes, with perivascular infiltration.
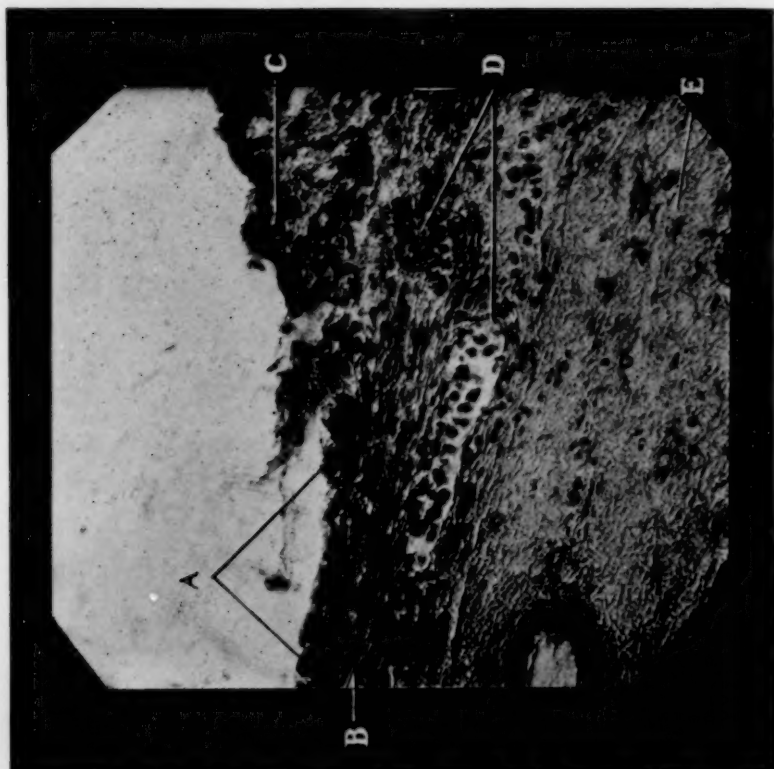
FIG. 4.—A, Base of ulcer showing absence of epithelium. B, Thickened basement membrane. C, Epithelium at edge of ulcer. D, Blood-vessels filled with leucocytes. E, Œdema of submucosa.

FIG. 5.—Taken from centre of muscular layer. A, Muscle. B, Large blood-vessels filled with polymorphonuclear leucocytes which can be seen invading vessel wall. C, Perivascular infiltration. D, Connective tissue.
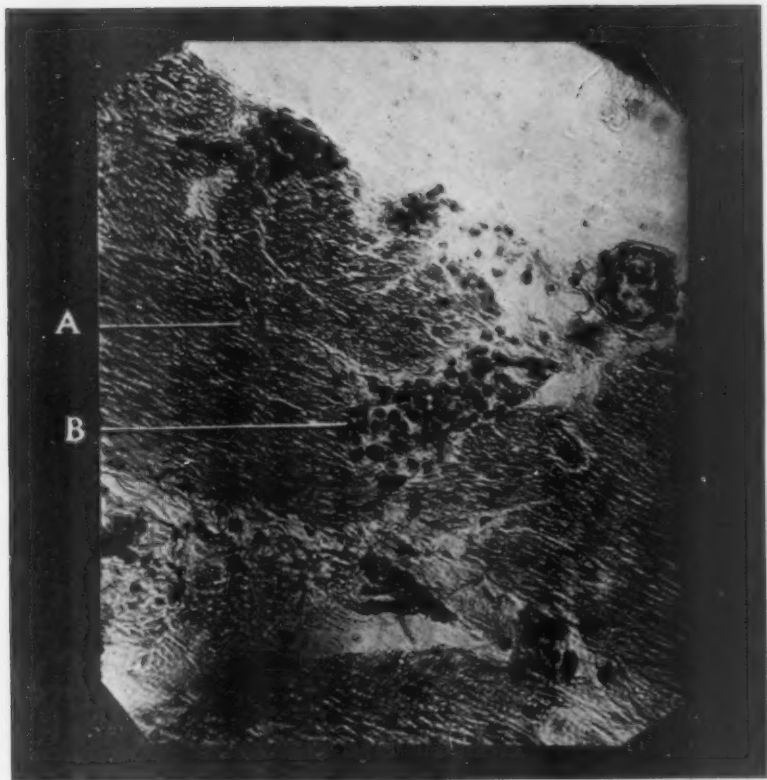
Fig. 6.—Taken from fibrous coat of bladder. *A*, Fibrous tissue. *B*, Blood-vessels filled with polymorphonuclear leucocytes which can be seen within the vessel wall. Also perivascular collection of leucocytes.

during an attack of typhoid fever, the other following an operation. The remainder can ascribe no probable cause.

In none of our cases has there been any evidence whatever of a gono-coccal infection. The condition is not secondary to inflammatory disease of the pelvic organs, for no such condition has been demonstrated either by vaginal palpation or intra-abdominal examination. From the fact that the pathology is always limited to or is most extensive in the bladder vertex, one might consider the possibility of its being associated with disease of the urachus, but we have found no evidence of this.

Hunner reports a sterile urine in his cases; such has not invariably been our experience. In one there was a pure culture of colon bacilli, in another staphylococci and non-hæmolytic streptococci. In three the urine was sterile, while in the remaining cultures were not made.

An analysis of the clinical and pathological findings suggests the possibility that a paracystitis may be the primary lesion, and that the changes seen in the bladder itself are purely a secondary manifestation.

Treatment.—We have run through the gamut of local applications in our treatment of these cases and have come to the conclusion that Hunner is correct in his statement that " no form of treatment will suffice except complete excision of the inflammatory area." As previously stated, cer-tain cases show periods of improvement lasting several weeks, which seem to be in no way dependent on treatment. Again, the symptoms may be somewhat relieved by applications of silver nitrate, silver iodide, carbolic acid, etc., but the relief is only temporary and nothing short of excision has in our hands given a permanent cure. We have not tried fulguration, but Hunner reports two cases in which this treatment pro-duced such severe pain that the patients refused further applications; he has also used the actual cautery wire which seemed to lessen the symp-toms somewhat, but did not cause healing of the ulcers.

Operative Treatment.—The operation consists in excision of the dis-eased area of bladder wall, and the limits of excision are determined not by the ulcerations, but by the distinctly outlined œdema. Anything short of this will result in failure.

Through a suprapubic incision, the bladder is exposed and opened, if possible, at a point previously determined by cystoscopic examination to be outside the area of œdema. The opening in the bladder is made sufficiently large to give a good exposure of its interior and the greatest care is exercised in handling the bladder to avoid an artificial œdema incident to trauma. By means of an illuminated vesical retractor, it is an easy matter to determine the limitations of the œdema, and these are marked by a series of linen traction sutures, passed deeply into the bladder wall to prevent their cutting out. Small ulcers which were plainly seen through the cystoscope in a well-distended bladder may at operation be difficult to locate at first glance. They appear as small, red spots which bleed easily on being touched with a cotton-covered probe.

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After placing the traction sutures, the bladder is freed as much as necessary and the area outlined by the sutures is excised. Ideally, the operation should be extraperitoneal, but occasionally, in spite of care, the peritoneum will be opened during separation of the bladder; we have seen no ill results follow. After complete hæmostasis has been obtained the bladder is closed with a two-layer suture of catgut, the first being submucous, the second intramuscular, and both of the Cushing type. A suprapubic drain is placed in the bladder through an angle of the incision, and a Mikulicz drain is placed in the prevesical space, well away from the suture line in the bladder wall.

Post-operative Treatment.—The Mikulicz drain is removed in forty-eight hours, the bladder drain at the end of ten days. The bladder is irrigated daily through the drain, with a catheter in the urethra to avoid the danger of over-distention. After removal of the tube we have found it advisable to continue the bladder irrigation, using a weak silver solution, until the healing is complete. The patient is instructed to retain the urine as long as possible in order to hasten the restoration of the bladder to its normal capacity, which requires, as a rule, about two months.

Results.—Eight of our cases have been operated upon, one by Doctor Hunner and seven by Doctor Clark. In all of these, various methods of treatment were tried and in none was more than a temporary lessening of symptoms obtained.

The first case, who had been under our care for some time, consulted Doctor Hunner, who operated upon her two years and a half ago; this patient is cured after many years of intense bladder symptoms. The time since operation in our cases is as follows: Case I, two and one-half years; Case II, two years; Case III, twenty-three months; Case IV, twenty-one months; Case V, sixteen months; Case VI, nine months; Case VII, three months; Case VIII, two months. We have followed the post-operative course of these patients very carefully and have a written or verbal report of all up to date. Seven have been cured, and in each the bladder capacity has been restored to normal. Case II had a urinary fistula at the site of the suprapubic drain for several months, but this has closed and the patient is now free from bladder symptoms. Case III was well for seven months when the symptoms returned during a severe attack of influenza. She has a recurrence of the œdema and ulceration on the left side of the bladder vertex and is returning to the hospital for a second operation.

In no series of cases that we have studied has greater appreciation of what an operation has done for them been shown than in the seven who have been cured. We have recently had the opportunity of making a cystoscopic examination of four of these patients, and the bladder in each presented a normal appearance with the exception of a thin scar line at the site of excision.

Non-operative Cases.—Case IX was examined two years ago on account of severe vesical symptoms. She had a myoma uteri the size of a two months' pregnancy and a typical lesion in the vertex of the bladder, with marked œdema and a single ulcer located in the median line, one inch posterior to the internal sphincter. She later consulted a surgeon in a neighboring city, who ignored the bladder findings and ascribed her symptoms to pressure of the tumor. A hysterectomy was performed, and at our last report there has been no relief of the urinary symptoms.

Case X has only recently been under observation. She was admitted to the hospital complaining of frequency and urgency of urination, with pain low down in the left side of the abdomen, referred to the left hip. On cystoscopic examination, œdema of the left bladder vertex was found, with an ulcer situated one inch to the left and one inch behind the left ureteral orifice, which is the first instance in our experience of ulceration near the base. Under confinement in bed and silver nitrate applications, the symptoms lessened, but the ulcer remained the same. Contrary to advice, she insisted on going home, and in a recent letter from her physician we learn that the symptoms have recurred with such severity that she desires to return for operation.

Summary.—1. Circumscribed pan-mural ulcerative cystitis is a distinct pathologic entity, characterized clinically by its chronicity, intense vesical symptoms, and a urine, usually sterile, containing a slight excess of leucocytes and a few red blood-cells; pathologically, by its location in the vertex of the bladder, presenting a sharply demarcated area of œdema with one or more small, superficial ulcers within this œdematous area. The inflammation affects the entire bladder wall and may involve the adjacent peritoneum.

2. The etiology is as yet undetermined, but it is probably due to infection of hæmatogenous origin.

3. Intravesical applications are of value only in giving partial and temporary relief. The best method of treatment consists in excision of the diseased bladder wall, the limits of which are determined by the extent of the œdema.

HYPOSPADIAS, WITH PARTICULAR REFERENCE TO THE OPERATION OF BUCKNALL

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It is the purpose of this article to report a case of peno-scrotal hypospadias cured by the operation of Bucknall,[1] and to bring to the attention of surgeons an operative procedure which—if we are to judge by all absence of mention of it in one of the most recent and authoritative text-books of genito-urinary surgery—has not received the recognition which its surgical soundness warrants.

The difficult problem involved in the treatment of hypospadias is essentially a problem of plastic surgery, and in an examination of the procedures hitherto devised one is more impressed by their ingenuity than by their agreement with the well-recognized principles on which this type of operation should be based.

The operations employed for the treatment of hypospadias may be briefly described as follows:

1. Operation of Nové-Josserand. *First Stage:* (*a*) Perineal urethrotomy. (*b*) Excision of urethral opening in the peno-scrotal region and closure by suture. *Second Stage:* Tunnelling of skin of penis from the urethrotomy orifice to the glans, and insertion of a free skin graft from the thigh which has been sutured into tubal form around a staff. *Third Stage:* Closure of perineal urethrotomy, if necessary.

2. Operation of Rochet: Identical with the operation of Nové-Josserand, except that a skin flap, swung up from the scrotum, is used to form the new urethra, instead of a free skin graft from the thigh.

3. Operation of Duplay. *First Stage:* (*a*) Perineal urethrotomy. (*b*) Two skin flaps are dissected up, one on each side of the urethra, and sewn together over a catheter, to form the new urethra. (*c*) The raw areas are covered with two skin flaps raised from the skin of the ventral surface of the penis. *Second Stage:* Closure of perineal urethrotomy when spontaneous closure does not occur.

4. Operation of Beck: (*a*) Skin flaps dissected up and sewn together as in the Duplay operation. (*b*) Raw surface covered by a skin flap rotated into position from the scrotum.

5. Operation of Wood. *First Stage:* (*a*) Perineal urethrotomy. (*b*) Raw edges made by two parallel incisions lateral to the urethra; a skin flap turned up from the scrotum and sutured to these raw edges, thus forming a new urethral tube. *Second Stage:* Closure of perineal urethrotomy, if necessary.

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[1] Lancet: Sept. 28, 1907, p. 887.

6. OPERATION OF ROSENBERGER. *First Stage:* (*a*) Perineal urethrotomy. (*b*) Raw areas made by two incisions, one on each side of the urethra; these raw areas sutured to skin edges made by suitable incisions in the skin of the abdomen. *Second Stage:* After healing between the penis and the strip of abdominal skin has occurred, the abdominal flap is dissected free. *Third Stage:* Closure of perineal urethrotomy, if necessary.

7. OPERATION OF LAUDERER AND BIDDER. *First Stage:* (*a*) Perineal urethrotomy. (*b*) Denudation of each side of urethra. (*c*) Corresponding denudations in skin of scrotum. (*d*) Penis flexed onto scrotum and cut edges, lateral to the urethra, sutured to corresponding cut edges in scrotal skin. *Second Stage:* After healing of penis to scrotum has occurred, the penis is dissected free and the raw area in the scrotum covered by suturing. *Third Stage:* Closure of perineal urethrotomy, if necsesary.

8. OPERATION OF BOUISSON: A flap is turned up from the scrotal skin sufficiently long to double on itself and thus form the floor of the new urethra, consisting of two thicknesses of skin.

9. OPERATION OF MOUTET: (*a*) A flap of scrotal skin is turned up to form the roof of the new urethra. (*b*) This is covered by a flap turned down from the pubis to form the floor of the new urethra.

10. OPERATION OF MAYO. *First Stage:* According to the principle of Van Hook a urethral tube is constructed from the redundant preputial skin, swung around on a pedicle, and tunnelled into place. *Second Stage:* After ten days a perineal urethrotomy is done, the pedicle of the skin flap divided, and the ends of the two urethras sutured. *Third Stage:* Perineal urethrotomy closed, if necessary.

11. OPERATION OF HAMILTON RUSSELL: Ingenious "clergyman's stole" incision by which narrow flaps are provided from the penile skin and are sutured to form a new urethra. A suprapubic cystostomy is done and the peno-scrotal opening of the hypospadias closed.

12. TRANSPLANTATION OPERATIONS: *Heteroplastic:* (*a*) Transplantation of urethra of animals. (*b*) Transplantation of ureter of animals. (*c*) Transplantation of vein of animals. *Homoplastic:* (*d*) Transplantation of urethra of cadaver—ureter of cadaver—vein of cadaver. *Autoplastic:* (*e*) Transplantation of vein from the individual.

It is not easy to determine what percentage of success has attended these operations, as occasional successes are more likely to be reported than repeated failures and analyses of large series of cases are rare. It is notorious, however, that the general attitude of surgeons, as regards this deformity, is one of pessimism, and the statistical analyses which do exist hardly justify the enthusiasm which the occasional (perhaps unfortunate) success of an unsound operation seemed to warrant.

If one scrutinizes these operative procedures by the criteria of sound plastic surgery not one of them meets the tests. These well-established principles are as follows:

1. *In every plastic operation there is an element of chance; the possibility*

of complete failure should always be taken into consideration and the question asked whether, in case this occurs, the patient will be worse off than before. In many plastics (the cure of simple harelip, for example) the chance of complete failure is so slight as to be negligible; in others (for example, exstrophy of the bladder) the condition is so distressing and carries such a threat to life that one is justified in taking large chances. Peno-scrotal hypospadias has no place in the former class; it does not quite belong in the latter.

2. *Plastic operations should be devised so that broad surfaces, rather than cut edges, are approximated.* This requirement is often impossible to meet, but the great success of the imbrication operation for inguinal hernia illustrates what may be accomplished in the repair of large defects (even when the material at hand appears inadequate) if the operation used is sound in this fundamental principle.

3. *Tension must be avoided at all stages.* Sutures should be used not to drag tissues together, but to tack them in position. Fine suture material should therefore be chosen which will break if strain is put upon it.

4. *Circulation of flaps must be reasonably preserved.*

5. *Flaps must be held in position without the use of elaborate retention dressings.* These are seldom efficient and therefore give a false sense of security. When not efficient they are usually harmful.

6. *The repair of the actual defect should be done in one stage;* operative difficulties are always greater at the second than at the first stage. If a second stage operation is needed, it should be for purposes of reinforcement and not, therefore, really an essential part of the plastic.

7. *The purpose of a plastic is the permanent and not the temporary result. Flaps should, therefore, be devised to allow for contracture,* and ultimate success planned for, even at the expense of neatness in the immediate result. The importance of this principle is well illustrated in the operation for simple harelip. A practically perfect immediate result is quite easy to obtain, but the shortened upper lip and dimple which so often develop later might have been avoided if the flaps had been more generously cut and the surgeon contented with a " lumpy " immediate result.

8. *The probability of success in a plastic is always greatest, other things being equal, if infection is absent.* Yet it is striking that some of the most brilliant successes are obtained with considerable constancy in regions of the body where infection is necessarily present. The primary healing which occurs after extensive resections of the lower lip and the practically invisible scar which often results, illustrate the possibilities of plastic surgery even when infection cannot be excluded.

It is clear that only rarely can all these requirements be met. The imbrication operation for hernia is, indeed, one of the few plastic operations which are sound in every respect. It is equally clear that success in this field has often been achieved by operations whose fundamental principles are open to criticism. This is certainly true of the operations for

hypospadias. Yet an examination of these procedures, as to their surgical soundness, will emphasize the great superiority of the Bucknall operation and justify the hope that by its use the results of the treatment of hypospadias will be improved.

1. *Operation of Nové-Josserand.*—The whole success of the operation depends on the take of a free skin graft, applied in an infected region and in a position where complete rest (essential to the success of a graft) can neither be obtained nor approached. Success by this method would be a lucky chance. Similar criticism must be made of the *Operation of Rochet.*

2. *Operation of Duplay.*—Burghard has stated the case correctly. This operation " so simple and apparently satisfactory on paper is practically useless; the parts are too small and the tissues are not sufficiently abundant. It is often difficult to draw the flaps together without strangulating the penis and some amount of sloughing is quite common."

3. *Operation of Beck.*—The formation of the urethral tube depends on the healing of cut edges rather than flat surfaces; the skin used for this tube is disturbed by dissection and usually drawn together under tension; the rotation of a rather long scrotal skin flap with a small pedicle is a bad feature.

4. *Operation of Wood.*—The skin flap is badly devised.

5. *Operation of Rosenberger.*—A good principle is suggested, but the practical difficulties are great.

6. *Operation of Lauderer and Ridder.*—This operation is correct in principle; there is no unnecessary dissection, no flaps are used, tension is avoided, the parts are approximated in unforced position. The sound idea on which it is based is adopted by Bucknall, but very greatly improved.

8. *Operation of Bouisson.*—Thoroughly unsound in every particular.

9. *Operation of Moutet.*—Essentially a flap operation and the flaps are not well devised. Moutet's account of the result in his own case is as follows: " The pubic flap sloughed entirely; the scrotal flap failed to heal "; " failure was complete."

10. *Operation of Mayo.*—The success of the operation depends entirely on the viability of a long flap swung into unnatural position. Even if this lives the operation is a failure unless the suture of the ends of the two urethras, made at a second stage, also heals.

11. *Operation of Hamilton Russell.*—Ingenious but unsound.

12. *Transplantations.*—The objections to heteroplastic and homoplastic grafts are well known; one can only regard the occasional success of *any* free graft, placed in a position where neither the crudest cleanliness nor immobility can be obtained, as a lucky chance.

The operation of Bucknall consists of the following steps:

1. *Correction of the curvature* of the penis, if this is indicated, is made in the usual manner. A sufficient period of time is allowed to elapse (not less than three months) before the cure of the hypospadias is undertaken.

2. *The Plastic Operation.*—(*a*) The penis is laid back on the pubis and two parallel incisions (¼ inch apart) are made in the skin on the ventral surface of penis and scrotum; these incisions are prolonged laterally at either end by small incisions, about ¼ inch in length, made at right angles to them (Fig. 1, *a* and *b*). I have found it convenient to place four traction sutures at *c, d, e,* and *f.*

(*b*) Two lateral flaps are dissected up, leaving the median strip of skin untouched (Fig. 2). This strip will form the new urethra, the penile portion (marked " a ") its roof, and the scrotal portion (marked " b ") its floor. Each lateral flap should be about ¼ inch wide and the median strip the same width.

(*c*) The penis is flexed onto the scrotum with the hypospadiac opening as a hinge; the lateral skin flaps are thus brought into flat approxi-
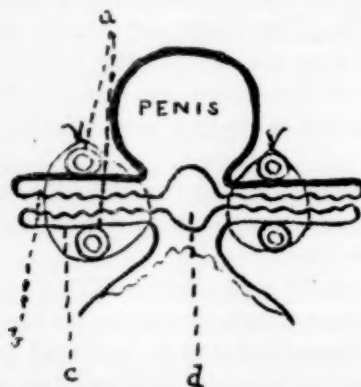

Fig. 5.—Schematic cross-section showing the result of the first stage of the operation (after Bucknall). *a*, rubber tubes; *b*, lateral skin flap, penile portion; *c*, lateral skin flap, scrotal portion; *d*, new urethra.

mation with each other, like the leaves of a closed book, and in this position mattress sutures are applied, as shown, Fig. 3. These sutures are tied over small rubber tubes, one of which is represented (Fig. 3, *a*) by a dotted line, the corresponding tube on the lower flap being omitted for sake of clearness. The method of applying the sutures to produce approximation of the median skin flaps without having them penetrate the new urethral tube is shown in Fig. 4. The finest suture material should be used and a No. 6 catheter inserted and fastened to the glans with a stay stitch. The catheter should be inserted before the mattress sutures have been applied; it is omitted from the illustration for the sake of clearness. The relations after completion of this stage of the operation are shown in the schematic cross-section represented in Fig. 5. No dressing should be used. A chloroform mask, suspended from a gauze bandage around the waist, with the bell of the mask lying over the scrotum, provides the best protection from the bedclothes. Bromides should be given for pain and to prevent erections. The end of the catheter should be allowed to lie in a urinal containing
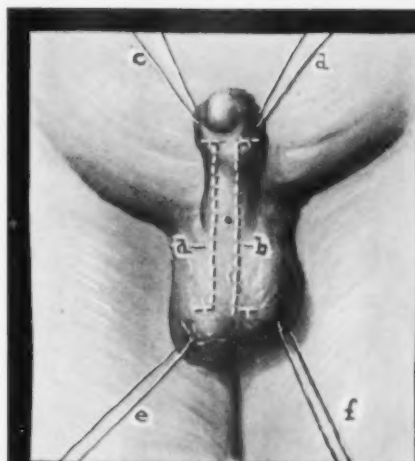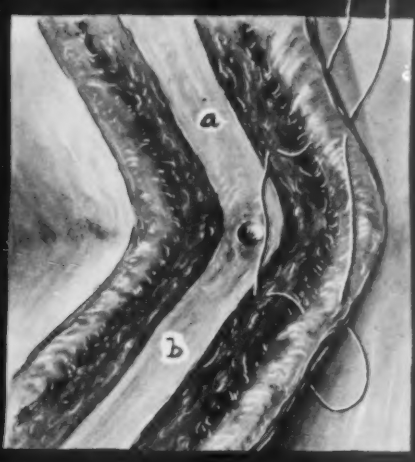
FIG. 1.   FIG. 2.

FIG. 3.   FIG. 4.

FIG. 1.—The first incisions are represented by dotted lines (*a* and *b*). Stay sutures hold the penis and scrotum in place (*c, d, e, f*).

FIG. 2.—Lateral skin flaps have been dissected up. A central strip of skin remains of which the upper or penile portion (*a*) will form the roof, the lower or scrotal portion (*b*) the floor of the new urethra.

FIG. 3.—The penis has been flexed, with the hypospadias opening as a hinge, and the lateral flaps are being sutured over rubber tubes; one of these tubes is represented by the dotted line (*a*), the corresponding rubber tube on the lower flap is omitted for purposes of clearness.

FIG. 4.—An enlarged drawing, showing the way the suture is laid, so as to approximate the skin edges (for the formation of the new urethral tube) without penetrating them. *a*, penile skin; *b*, the scrotal.
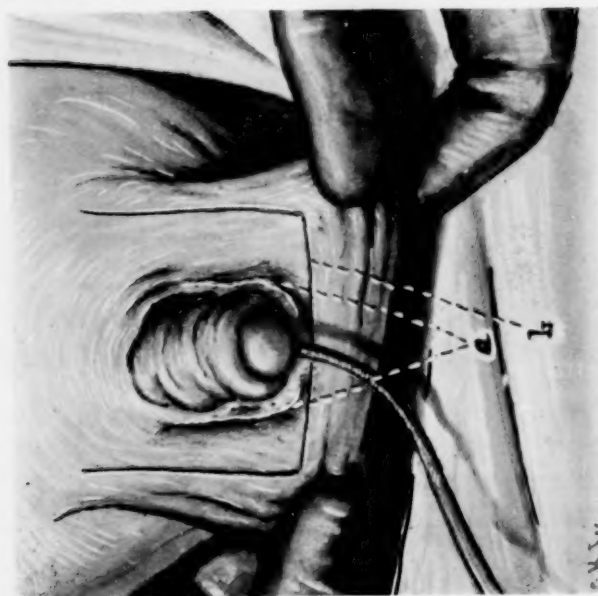
FIG. 6.—First step in the second stage operation. The penis has healed in the scrotal bed; the edges of the lateral skin flap are seen at *a*. The skin incision is shown at *b*; it is purposely represented as made further from the penis than is necessary in order to indicate that one should err on the side of lifting up too large, rather than too small, a flap. A rubber catheter has been inserted in the urethra, in order to protect it during the dissection of the penis from the scrotum.
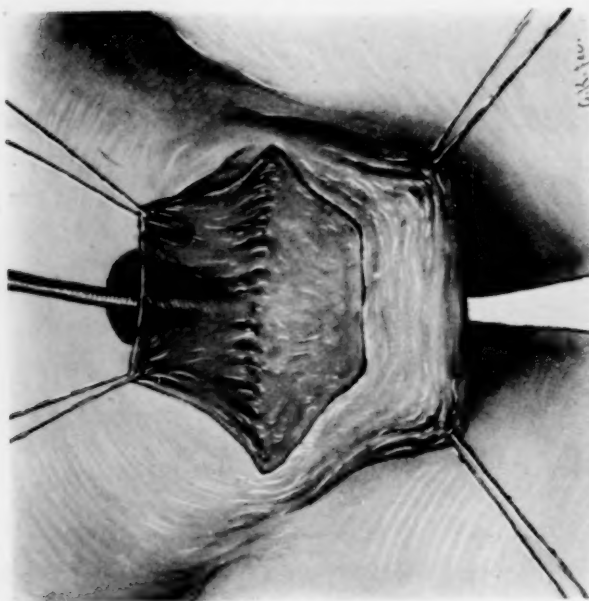
FIG. 7.—The dissection of penis from scrotum has been completed; the new urethra, distended by the catheter, can be seen bulging against the skin flap.
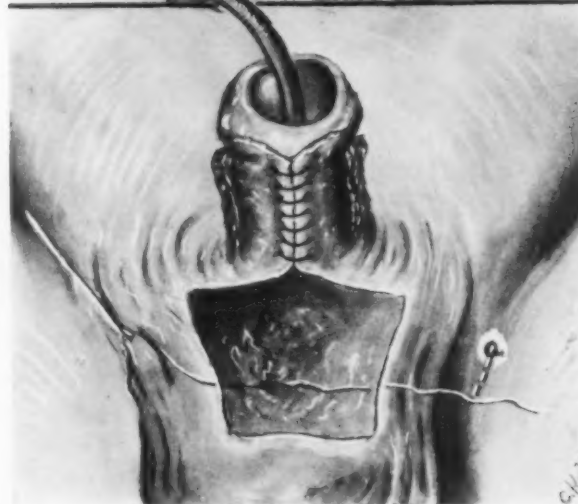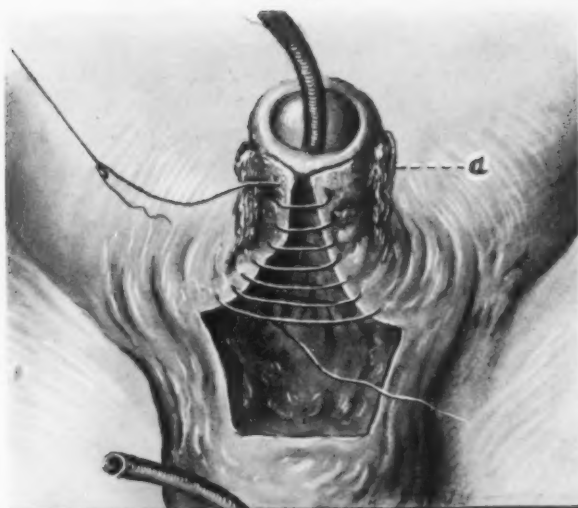
FIG. 8.

FIG. 9.

FIG. 8.—Suture of scrotal flap begun; interrupted and not con-
tinuous suture (as shown by the artist) should be used. *a*, cutaneous
wing. formed by the healing of the two lateral skin flaps, sutured at
the first operation.
FIG. 9.—Suture of scrotal flap completed. One suture has been placed,
beginning the repair of the defect in the scrotum.
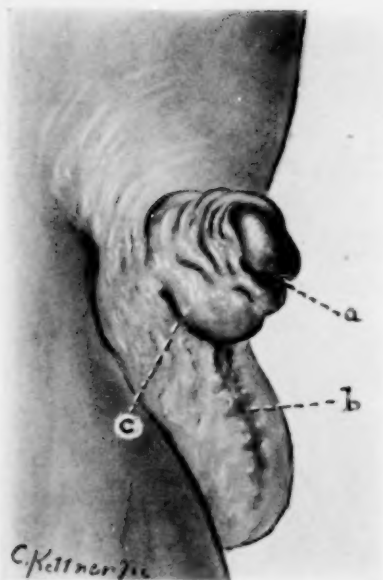
FIG. 11.—Final result. *a*, present urethral
orifice; *b*, scar in scrotum at site of area from
which scrotal flap was raised; *c*, site of previous
urethral orifice (at peno-scrotal junction).
From a cosmetic point of view the result is
"lumpy," because all redundant skin has pur-
posely been left for future plastics. From a
functional point of view the result is perfect.

boric acid solution. The catheter should be removed on the fifth day and alternate stitches on the same day; the remaining stitches may be removed a few days later. When healing has occurred between the lateral skin flaps, which have been sutured in flat approximation, the penis is fixed to the scrotum, the hypospadiac opening is closed and a new cutaneous urethra has been formed which now opens near the glans (Fig. 6).

(d) The second stage of the operation is not undertaken to complete the cure of the hypospadias, which has been accomplished by the first stage, but to restore the penis to its normal position and to cover raw areas. It should be undertaken not sooner than twenty-one days after the first operation; it should not be considered until healing from the first operation is absolutely complete, no matter how long this takes. Indeed, it is probably wise to discharge the patient from the hospital for a period of two or three weeks, rather than be tempted to intervene too
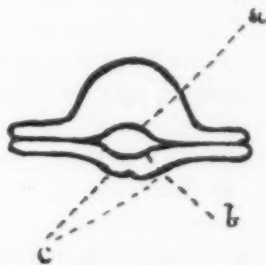
FIG. 10.—Schematic cross-section to show the final result. *a*, roof of urethra, formed of penile skin; *b*, floor of urethra, formed of scrotal skin; *c*, reflected scrotal skin flap.

soon. The skin incision is made as shown in Fig. 6, *b*, though not so far out on the scrotum as represented in the illustration; this feature is purposely exaggerated in order to emphasize the fact that abundant skin should be taken (more will be needed than on first thought seems necessary), and that as much skin as desired may, with impunity, be lifted up from the scrotal redundancy. A catheter should be inserted before the dissection is begun, to protect the urethra from injury, and the dissection carried out as shown in Fig. 7. The edges of this skin flap are sutured as shown in Fig. 8, except that interrupted sutures should be used, rather than a continuous one, as illustrated. The result, after these interrupted sutures are tied, is shown in Fig. 9.

The raw area in the scrotum is covered by means of a few sutures placed as shown at *a*, Fig. 9. No retention catheter is needed. A cross-section of the penis at the end of the operation is schematically represented in Fig. 10; the method of formation of the new urethra from penile and scrotal skin may here be clearly seen.

The patient treated by this operation was a boy four and one-half years of age, of active mind and sensitive nature, whose morale

was beginning to be undermined by the humiliation of abnormal urination. The functional result was a complete success; when the patient left the hospital he was able to void in the normal manner and to project a good stream. The cosmetic result (Fig. 11) is intentionally " lumpy," as all redundant skin was purposely left, against the needs of possible future plastics. It would, of course, have been quite simple to trim up the skin and improve appearances. I did not undertake to bring the urethral opening out of the glans; the vital part of the operation is to advance the opening from the perineum to the region of the glans. If this is accomplished, the relatively simple glandular operation can be done later, if for cosmetic or other reasons this seems advisable.

The simple and entirely sound operation of Bucknall should not be complicated by attempts at cosmetics until the real purpose of the operation (the cure of the hypospadias) has been achieved.

PROJECTILE FRACTURES OF LONG BONES

A COMPARATIVE MECHANICAL STUDY

By Kellogg Speed, M.D.

OF CHICAGO

IN the handling of many hundreds of gunshot fractures, glancing hastily at times at an X-ray plate to note the presence or absence of foreign bodies, it always has been my intention to study these lesions so that they could be reduced to simple terms. The comminution present made many skiagrams appear as bone hash, but these severe fragmentation fractures are really exceptional.

To understand the mechanism of fracture—by that is meant the everyday closed fracture of civil life—we must consider bone from a physical standpoint. For study we can take any long bone as an example, because they are the most concerned, the skull alone excepted. Certain physical properties of long bones must be kept in mind. Bones possess elasticity, strength and toughness, and are governed by the same physical laws as similar supporting substances subjected to stress and strain.

In long bones it has been proved that the compacta or hard shell is intended to furnish rigidity and form, while the cancellous inner and terminal portions possess much greater strength to resist forces applied at any given point in the normal axis of the supporting trabeculæ. For example, the condyles of the femur or the os calcis, both of which bear much of the jar and stress of weight bearing, are composed of a delicate cancellous bone with an egg-shell compacta on the outer surface. If force is applied in the normal direction of weight bearing or muscle pull, this cancellous bone will withstand enormously. Wolff's law, so often forgotten, states that the structure of bone is determined by the internal reaction of the individual bone to the body weight and the stress and strain of muscular activity.

The general mechanism of the ordinary fracture of civil accident must first be understood. When the body suffers any direct trauma a transmission of the stress to the supporting bones results. These stresses or forces can be reduced to simple terms and to two main types—compressional force and torsional force.

First, compression force operating against a long bone acts as pressure does against a rod or beam. If we consider the compression force acting against the bone at a given point, trying to effect a solution of its continuity by crushing in the surface, we must also understand that at a point directly opposite in the line of force, this same power is attempting to tear the bone asunder. That is, the shaft of the bone is being subjected to a compression force at one point, its ends being firmly fixed by attachment to the rest of

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the body, and at an opposite point is being split asunder by a force tending to overcome its tensile resistance. To simplify, let us call one part of this force compressional, the other tensile. It has been determined in the laboratory that a bone shaft will give way to the tensile force sooner than
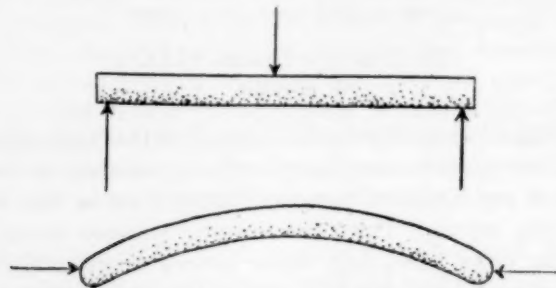

Fig. 1.—Diagrammatic representation of the two methods of compression of a long bone. Upper figure, compression, the middle acting in the direction of the arrow, bone held by attachments above and below for counter pressure. Lower figure, force applied in the longitudinal axis leading to bending at center with compression there.

to the compressional. In fact, a ratio of a bursting compressional force of 3 is required to equal a tensile force of 2.

Consequently, when subjected to these forces a bone gives first from the tensile force, especially when there is a relatively slow-acting force which has not much more than sufficient power to break the bone. The planes of cleavage, as shown by a line in the skiagram, start on the tensile side, that is the convex side when the bone bends, at a point about opposite the com-
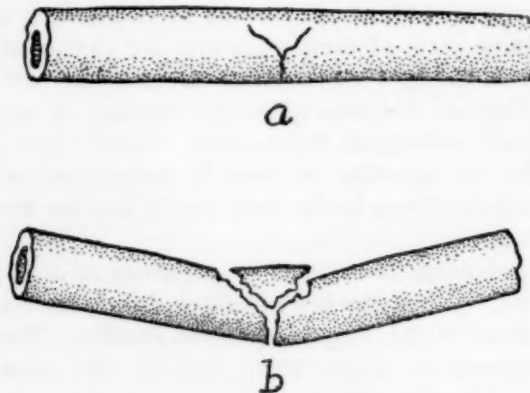
Fig. 2.—a, Diagrammatic compression fracture. The bone starts to give on the tensile sides; planes of separation diverge as it bends. b, Resulting fracture with triangular shaped piece broken out on compression side.

pression point. The bone being somewhat elastic is bent slightly out of its long axis and in giving arches more and more so that these planes of separation tend to assume an oblique direction. If two start and assume an opposite direction, we see the breaking out of a triangular-shaped piece

FIG. 3.—Illustration of torsion force acting on long bone shaft.

FIG. 4.—Unrolling of bone shaft results following torsion violence; spiral fracture.

FIG. 5.—Tracing of skiagram in compression fracture of the leg. Note the oblique plane of separation and the triangular fragment broken out on the compression side.

FIG. 6.—Compression fracture of both bones of the leg, skiagram tracing. Violence offered on the fibular side.
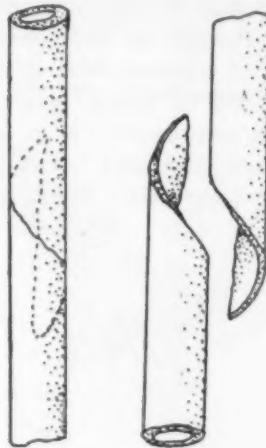
FIG. 7.—Similar to FIG. 6. Skiagram tracing.

of bone on the side of the compression. Only when the compression force is great enough to overcome the bone instantly do we get a transverse line of fracture—the so-called shearing fracture. Any force of less power and of slower action invariably results in an oblique fracture. If the compression is in the longitudinal axis of the bone we may get the same resulting break, or more rarely, longitudinal cracks running up the long axis. These are frequently aided by the various

FIG. 8.—Compression fracture of femur. A quickly acting, ponderous force with almost transverse fracture. Skiagram tracing.

FIG. 9.—Skiagram tracing spiral fracture of the femur from torsion violence. A glance at a skiagram is sufficient to differentiate the two general types of fracture.

complicating vibrations resulting from the jars of the trauma causing the loss of bone continuity. Buckling and green-stick fractures are also examples of compression fractures.

The second common force in fracture is torsional violence, which results from twisting and affects particularly bones of the extremities. This causes spiral fractures. We find these fractures in the leg and arm when the limb is twisted by being caught in falls or when the body is twisted with the limb fixed. Usually spiral fracture of the leg is caused by the foot being turned violently outward, as in slipping or catching against an object. So regular is this mechanism and so universal the outturning of the foot that

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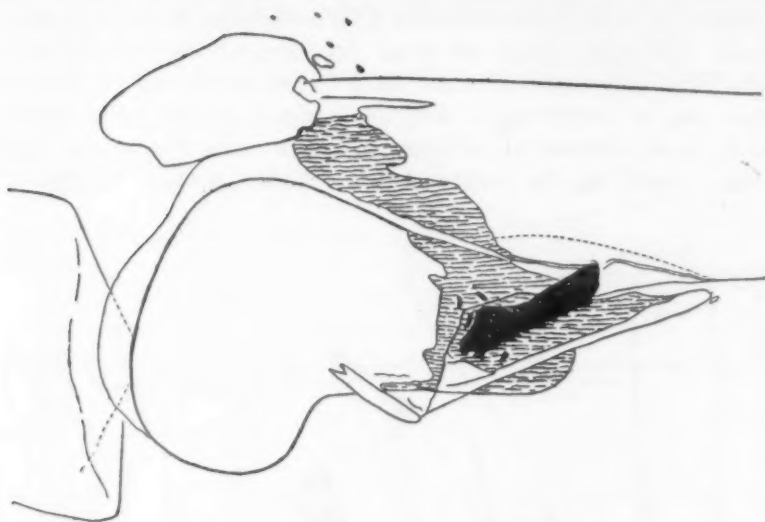FIG. 10.—Gunshot fracture of femur from shrapnel. Bone struck on inner lateral surface. Oblique fracture with bone fragment broken out on compression side and turned down.
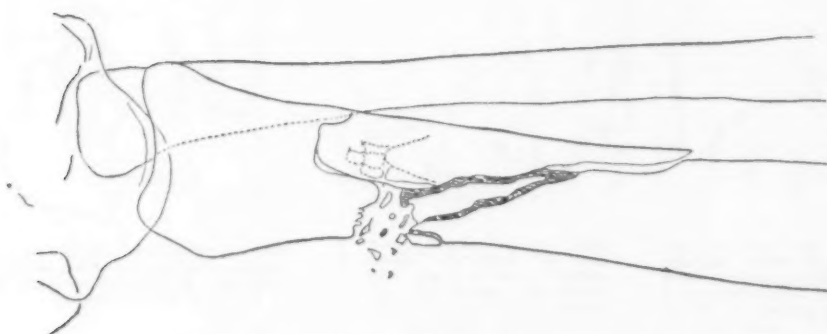
FIG. 11.—Gunshot fracture of tibia; missile passed out. Purely compression in type with large adherent triangular fragment.
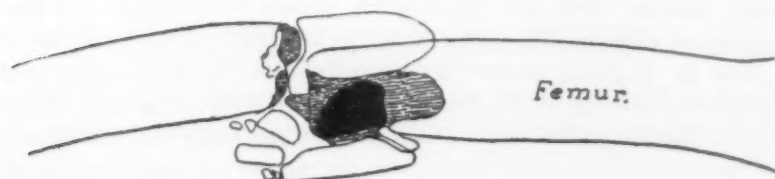
Femur.

FIG. 12.—Gunshot fracture of femur; compression by piece of shrapnel which remained in the bone.

we can say that spiral fractures of the right leg are left-handed, that is— they start at a point in the bone and pass downward to the left as a spiral staircase. Likewise, nearly all spiral fractures of the left leg are right-handed. The only exceptions are those in which the leg or foot is fixed and the body is twisted in a direction opposite to the usual mechanism. When torsional violence of sufficient power to cause fracture is applied to a long bone, which may be compared to a cylinder, it starts to give at some

FIG. 13.—Gunshot fracture of ulna by swiftly moving missile which passed on. Note the greater comminution and smaller fragments, a few of which are displaced.

FIG. 14. — Gunshot fracture of humerus. Some metal remains in bone. Low momentum, giving large adherent fragments and compression fracture.
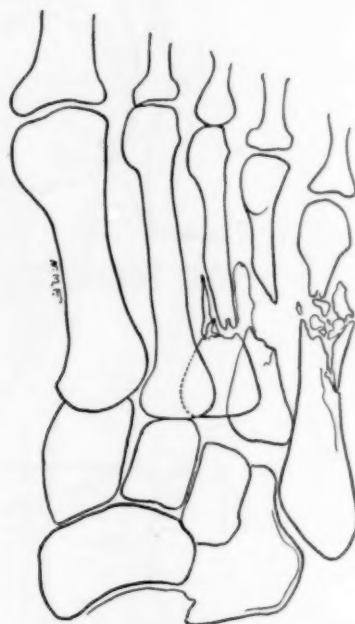
FIG. 15.—Gunshot fracture of metatarsals. Missile carried on, taking many fragments of fourth bone with its imparted velocity.

point on the surface and unrolls in its continuity. The sharp-pointed ends of the fragments are found on the same surface of the bone.

It is true that every fracture will not submit to such simple physical analysis—because there are certain other factors which enter and spoil the pure types of either compression or spiral fracture. There may be flexion of a limb by doubling under—the man falls as the bone gives way—or there may be a change in the line of support of body weight, or frequently there are added rapid vibrations and jars of the body and limb incidental to the trauma. These may complicate the planes of bone separation, but it is surprising what a large percentage of fractures yield to this simple analysis. The time will come I hope when we will all appreciate these con-

ditions and after examination of X-ray plates in a given case can tell something of the cause. It may influence our nomenclature, furnishing one based on mechanics.

The application of these points to gunshot or projectile fracture seems
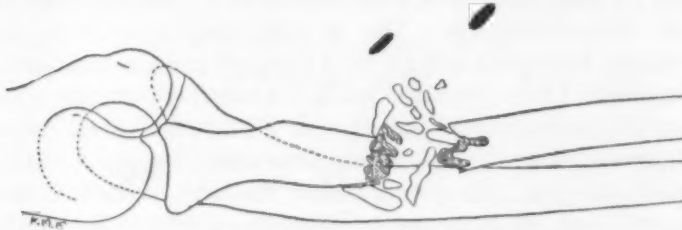
FIG. 16.—Gunshot fracture of radius. Shrapnel of fairly high velocity, causing smal fragments and some displacement of them; compression fracture.
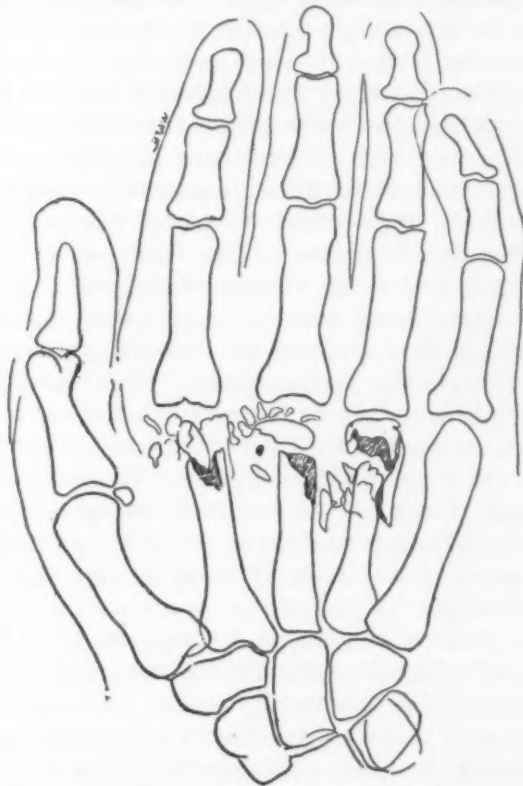
FIG. 17.—Gunshot fracture metacarpals from high velocity bullet. Note compression fracture comminution, small fragments with displacement.

far fetched. It is not, however, as we can see when we compare the skiagrams of simple civil fractures with those of fractures produced solely by projectiles.

When a man is struck by a bullet or piece of shrapnel in a long bone such as the tibial shaft, what happens? The bone at that point is subjected

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to a compressional violence of varying degree depending on the momentum of the projectile. If struck squarely with no angularity we would expect that any resulting fracture of that bone would appear much as a compression fracture in civil life. It does. There is the same oblique or transverse plane of bone separation with frequently a triangular portion broken out on the compression side. This is particularly true if the projectile's velocity has not been great and the total force offered has been just sufficient to cause a break. If the projectile has had a very high velocity it may act as in the case of a conical-nosed bullet—over a very small area, causing puncture, and passing clean through a long bone shaft, leaving a track but with no complete fracture. No pure gunshot fracture then could be a spiral fracture, and none of them are. Sometimes a man falls simultaneously with a gunshot fracture of a limb, which might be twisted, and some spiral character of the bone break might appear, but that rarely happens. If the projectile passes through at high velocity it imparts this velocity to the immediately surrounding bone with which it comes in contact, so that there is more comminution and a wider displacement of the bone fragments. The same rule applies to multiple foreign bodies, as broken-up pieces of shrapnel striking a bone in a small area—there is more comminution.

Gunshot or projectile fracture is then merely compression fracture, sometimes with a wider displacement of loosened fragments. We can agree with Delorme that the dimensions of the fragments in gunshot fracture are inversely proportional to the velocity of the projectile—but will show the result of the mechanism ascribed to compression fracture. Put in another way—the less the velocity of the projectile, the larger the adherent fragments and the smaller their number. With very great projectile velocity there are fewer adherent fragments, but there is a greater total number and they are scattered widely in the track of the projectile, even penetrating into the surrounding soft parts. These small swiftly driven bone particles may break out of the limb through orifices they make themselves, probably taking on some of the rotatory motion from bullets fired by rifled guns. Such fractures result in loss of substances from the bone's continuity.

Any clinical division of gunshot fractures such as "fracture with loss of substance," "fracture with comminution and wide fragmentary separation," "perforation fracture," "gutter fracture" and "contact fracture" simply leads to confusion. They can be called compression fracture, and the description of the displacement of fragments can be added.

A FORM OF SPLINT AVAILABLE IN THE TREATMENT OF FRACTURES OF THE NECK OF THE FEMUR

By Harvey C. Masland, M.D.

of Philadelphia, Pa.

Fractures of the neck of the femur occur most commonly in elderly perons. They frequently arise from a comparatively light traumatism, and indicate thereby a lowered vitality and structural weakening of the part. Experience has taught that these patients bear confinement in bed and the presence of cumbersome dressings very badly.

Probably most surgeons treat these cases with sand bags and extension. Imperfect rigidity of the parts is thus obtained.

Plaster bandages enclosing more or less of the trunk and the thigh are used by many. This dressing looks good from a superficial standpoint, but it is worth while to consider some features that would demonstrate it to be an unsafe procedure in practice. To apply a cast to the trunk, the patient must be upright or else horizontal and supported at the pelvis and the shoulder blades. Of course, the latter position is chosen in fracture of the femur neck. In each of these positions the soft tissues, and to a less extent the skeleton, assume a different conformity and relation to each other. Both of these relations are quite different from the outlines assumed when the patient is recumbent on a bed supporting the weight of his body along the full extent of the trunk. In an obese person this is obvious. Further, we must not overlook that the vertebra are sagging in the middle while the body is on a two-point suspension with the spines projecting more than they naturally do. Even though the cast has been carefully and expertly applied, it fixes the tissues in a relation not normal to any lateral supine or erect position the patient may subsequently assume. This factor is of more moment in an aged person and explains the great discomfort frequently experienced, and the fact that bedsores are not uncommon.

I was prompted to devise the splint here described to meet an emergency last summer. The patient was a woman seventy-four years of age and weighing 250 pounds. For three days I used sand bags and extension. She complained bitterly of pain in the joint and the back. She could not sleep. There was an erythema over the sacrum due, however, to pressure from an improperly adjusted vent in the fracture bed. My thought was to devise a splint that would hold the thigh rigid to the pelvis, give extension, and at the same time allow some change of position and opportunity to care for the back. A splint with straight sides as in the ordinary Thomas splint can hardly be prevented from turning sidewise. It occurred to me that following the contour of the trunk and

the limb, the changing curves would prevent this turning. An arm up the back, as in the long Thomas splint, did not appeal, because of the objectionable back pressure and because I doubted that the same degree of rigidity could be secured.

The trunk and limb were placed in the position to be made permanent. A tape line was extended parallel to the trunk line from the axilla to 8 inches beyond the foot. A ruler at right angles to the tape line gave the distances at intervals of 2 inches on the tape line to the opposing side of the body. At the pubis the distances to the inner side of the limb were also started and noted with the distances to the outer side. Marking a straight line on the floor these distances were measured off. Drawing a line through these points gave me the contour of the trunk and both sides of the limb, while the patient was in her natural recumbent position.

Using ordinary bale strap iron I bent it to conform to the line of the trunk and the outer side of the limb. Extending about 8 inches beyond the foot the iron was bent back and made to conform to the curve of the inner side of the limb.

At the pubis a cross-section of the thigh is roughly elliptical. The depth of the thigh was noted. At the axilla and waist line holes were drilled in the iron and pieces of flexible tin about 20 inches long and $1\frac{1}{2}$ inches wide were riveted on, thus giving arms about 10 inches long. Holes were also drilled for riveting on the perineal ring. This ring is roughly elliptical with the lower side flattened more than the upper (Fig. 1).

The iron was padded. To prevent soiling of the ring from urine I covered it with Dura leather strips laced on through eyes made for the purpose.

I fashioned this iron in less than an hour's time. With the measurements any instrument maker, machinist, or blacksmith could produce it quickly. The artificial leather makes a neat appearance. In some parts it could be wrapped on as a bandage, but around the perineum I prefer it laced on, thereby preventing the urine penetrating the edges if the bandage were used.

The splint was bandaged snugly to the leg and to two-thirds of the length of the thigh. Adhesive straps held the tin bands firmly to the trunk. The tin bands were so riveted to the iron that they could turn a bit. This allowed the adhesive strips to be applied to different skin surfaces at each dressing. The rest of the body was exposed to inspection and proper care.

Extension can be applied from the cross arm beyond the foot. This projecting part can also be rested on a small sand bag, thus relieving strain. The patient can be turned and the side rested on a bolster for change of position.

I have used this splint in two cases. Both experienced immediate comfort gratifying to patient and doctor. The first patient had had an osteomyelitis of the other leg. Her only complaint now is that this leg
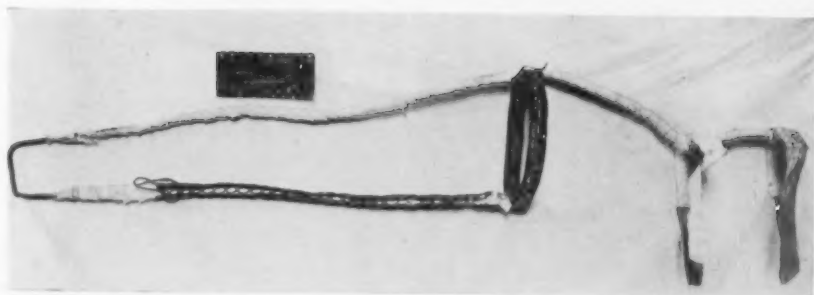
FIG. 1.—Splint for cases of fracture of the neck of the femur. Waterproof artificial leather, eyeletted (small section separate) covers the perineal ring and as much of the rest of the splint as desired.

is not as good as the leg that had been broken. She had no complications. I show the X-ray plates of the second patient taken at the time of and eight weeks after the fracture. She has firm union, good joint movement, and while the time is yet too short, she should ultimately walk without support. In this patient there had been poor circulation prior to the accident. In fact, vertigo and weakness were prime factors in her accident. She suffered during her illness not from the fracture, but from œdema and stasis in both her feet. It gave, however, no great trouble. The general health was excellently maintained.

In both of these cases there was displacement of the fragments. In the second case the lower fragment projected forward so markedly as to simulate an anterior dislocation of the hip-joint. In both cases manipulation reduced the deformity. In the first case there is no deformity; in the second a hardly perceptible shortening. Both these cases have convinced me that we should not let our fears of doing injury dissuade us too much against intelligent manipulation under anæsthesia relaxation to correct the deformity at the time of injury.

ANHYDROUS COCAINE SPINAL ANÆSTHESIA[*]

By James Ralston Wells, M.D.
of Philadelphia, Pa.

Before arriving at the exact title matter of this address, let us briefly review the subject of spinal anæsthesia or analgesia (because by this means of insensibilitation the protopathic sense is subdued before the epicritic, motor, or muscular senses). In 1885, Corning, of New York, attempted the first work on the spine to produce analgesia. For this he used cocaine, but did not enter the spinal theca. Quincke, in 1891, introduced the lumbar puncture, but it remained for Bier,[1] in 1898, to first perform a lumbar puncture for analgesic purposes. Using cocaine as his agent, himself, his assistant, and six patients as subjects, were given the initial doses. His results were most discouraging, all eight subjects had severe vertigo, vomiting, and headache. In 1900, Tuffier,[2] of Paris, reported 80 cases, cocaine used, with good results and no deaths. Reclus[3] reports six deaths with cocaine. In 1902, Perkins[4] reports 2345 cases and 16 deaths. In 1891, Giesel isolated tropococaine, Chadbourne named it a year later, then followed stovaine (Tourneau in 1904), and novocaine (Einhorn, 1904).

To continue, in 1905, Morton[5] reported 2066 cases, 1427 of which with cocaine, the balance with tropococaine, no deaths. Bier[6] reported 305 cases with no serious results. In 1908, Sonnenburg, Kunnel, and Allesardri collectively, have reports numbering 3235 cases with 3 deaths, while Bruning reports 3 deaths in 450 cases. Barker,[7] in 1908, in his first series of about 300 cases reports .6 per cent. mortality, while in a subsequent series of 475 cases no deaths occurred. Strauss,[8] in 1909, collects a series of 22,717 with 7 deaths; Houghton 735 cases, no deaths; McGavin, 844 cases, no deaths; therefore, in this series from 1908 to 1914 of about 28,746 cases, the mortality is not over 1 in 1200. The Ryall[9] statistics (1911) report a general mortality of 1 in 13,000. Babcock[10] (1915) reports 1295 cases, no deaths. Yount,[11] in 1917, reports 5160 cases, 1 death; Jonnesco, 10,000, no deaths (1915–1917 mortality 1 in 16,000).

With this array of figures, some of which may have been reduplicated, and many more omitted or not recorded, we may draw the conclusion that spinal anæsthesia is gaining in popularity and losing in mortality. Is it a sky-rocket bursting brilliant, then falling, as it was spoken of by Wm. M. Perkins in 1902, or is it reaching its logical, useful level among our anæsthetics?

That it has a definite place in surgery is becoming a fact. More exact knowledge of the general underlying principles involved will lead to results more near perfection. The death-rate varies with the different

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[*] Read before the Philadelphia Academy of Surgery, January 5, 1920.

reports and at best no exact rate can be ascertained, because different surgeons in attributing death to anæsthetics include deaths in cases of advanced toxæmia and poor surgical risks, while others exclude them. The mortality may also be based on a series of one year's cases and referring to one drug only, while others cover a number of years, including from the earliest use of cocaine in its impure form, up to the most advanced technic and perfect isolation of the pure drug used. So one may report three deaths in three cases, while another may report thousands and no deaths, and all gradations between. Another point. While immediate operative mortality of spinal anæsthesia is higher than that of ether, the additional mortality from post-operative complications following ether narcosis would probably about balance them.[14]

Spinal analgesia may be condemned as dangerous, and it is not without danger, but in any case where a general anæsthesia is contraindicated, the use of any anæsthetic is a risk, as, for instance, in advanced peritonitis or strangulated hernia, in advanced cardiac or renal disease, in which many surgeons will advocate spinal analgesia. Why? Because they think there is less danger of death immediate or post-operative. Is this a fair trial for spinal anæsthesia? If it is *less* dangerous in these cases, why would it be more dangerous in the general run of surgical conditions where the chronic heart, kidney, or advanced toxæmia is not present?[12] There is no post-operative mortality nor delayed toxic state due to spinal anæsthesia (Sanders[13]).

We all have seen the picture of an acute abdomen, the set, anxious face of severe suffering, the distended, rigid abdomen, the rapid, bounding pulse, increased respiratory rate, and a pyrexia of possibly alarming proportions; to those who have never seen a case of this kind under spinal analgesia, to see the expression of pain practically gone, the rigid muscles relaxed, the general attitude of tranquillity supervene, is a revelation and one never to be forgotten, one that makes us think, whether it is wise to always subject such a patient to ether anæsthesia with its accompanying phenomena, the initial twenty to thirty minute struggle accentuating all conditions that we wish to avoid, *i.e.*, the congested flushed face, rapid respirations, hot moist skin, coughing and outpouring of mucus, a picture of stimulation and irritation.

In spinal analgesia we have a corresponding fall in diastolic and systolic pressure due to more or less paralysis of: (1) The bulbar centres. (2) Efferent vasomotor fibres which run in the lateral columns of the cord. (3) The vasomotor fibres which pass out with the anterior roots of the cord from the fifth dorsal to third lumbar segments.[15] Slow, shallow respirations, *reduced* pulse *rate*, thus a slower working heart against less resistance, skin pale, little or no moisture, muscles perfectly relaxed; in short, a picture of rest, corresponding to sleep. These phenomena reach their height in from ten to thirty minutes, depending on the agent, amount, and strength used, and then gradually return to normal, mayhap

before the operation is completed, and almost always before the proto-pathic sense returns.

After our initial stage of *stimulation* of ether anæsthesia, we *must* have a stage of more or less exhaustion. The patient no longer responds to ether stimula and we have the picture of a physically tired being, a drenched skin, lowered temperature, and we know in a short time the exhaustive vomiting will ensue which loses fluid, uses energy, adds to pain, and may possibly derange the operation in whole or in part.

All centripetal nerve impulses from the operative site being blocked in spinal analgesia at the posterior nerve roots, lessens that shock caused by trauma to viscera or raw tissues, that shock that is not controlled in general anæsthesia; also trauma *per se* is lessened due to the extreme flaccidity of the muscles, and in abdominal operations, in addition, the loss of the tendency of the intestines to protrude into the wound. Our patient is normal, additional shock is blocked, and the original shock is not added to, at least, and if a preliminary hypodermic of morphine or scopolamine, or both, had been given, we have a partial blocking of psychic phenomena. Rarely is there post-operative vomiting and a small proportion complain of headache for a day or so.

We may sum up the advantages: (1) Perfect analgesia. (2) Perfect muscular relaxation. (3) Absence of post-operative shock. (4) Absence of post-operative gastric disturbance. (5) Absence of post-operative motor restlessness, so often difficult to control in ether narcosis. (6) Retention of consciousness, thus allowing of deciding a point, as, for example, removal of two ovaries instead of one, as intended, also allowing of drug admin-istration, coffee, etc., by mouth. (7) Immediate resumption of gastro-intestinal activity if operative conditions permit.

Added to these: The extreme ease of retraction of muscles. The loss of intestinal tendency to crowd the operative field. The relief in spastic or paralytic ileus, at times removing the operative necessity entirely. (Babcock reports several cases of this kind.) The saving of one pair of hands for other purposes in the operating room. The small space neces-sary for the agent and paraphernalia, and the relative cheapness as com-pared to ether, etc.

In enumerating the disadvantages: (1) The retention of consciousness may also be classed here, for example, in a highly neurotic individual. (2) Manipulation of the stomach and intestines. This at times gives rise to a " sinking " sensation, which, in turn, causes untoward psychic condi-tions, but these are rarely dangerous to life. (3) After a given amount of the analgesic agent is injected it cannot be readily controlled. Theo-retically a tap in the lumbar region will drain off the cerebrospinal fluid containing the drug, and as the ependyma (choroid plexuses) of the cerebral ventricles produces the fluid rapidly, the cord and nerve roots may be washed from above down by this means.[16] (4) Ether or one of the general anæsthetics can be obtained in almost any place, and its admin-

istration in the majority of cases is not difficult; on the other hand, a spinal analgesic agent is neither obtainable in all places nor is its administration so simple. (5) Failure of analgesia is variously reported as from 4 per cent. to 9 per cent., due in most part probably to non-entrance, wholly or in part, into the subarachnoid space; it may also be due in part to an inert agent. This per cent. includes complete or partial failures, unilateral and delayed analgesia.

The indications and contraindications vary with different surgeons, their drug agent, technic, and experience. We may safely say the following lists agree with the majority of those who have had a sufficient number of cases to be capable of judging.

Spinal analgesia is indicated in: (1) Cardiac conditions, alone or plus broken compensation. (2) Renal conditions, especially in the presence of impending uræmia. (3) Pulmonary conditions other than (a) acute febrile tuberculosis; (b) large pulmonary effusions; (c) *large* intra-thoracic growths. (4) Inguinal, femoral, and ventral hernias. (5) Shock, if blood-pressure is not too low or falling, especially in railroad accidents to legs or pelvis, and severe burns or scalds. (6) Acute abdominal conditions, including appendicitis with or without peritonitis, peritonitis, intestinal obstruction, and paralytic obstruction. (7) Reductions of dislocations. (8) Operations on anal region, urethra, bladder, prostate, uterus, and appendages. (9) Plethora, atheroma, and chronic alcoholics. (10) Lastly, the large class we all know, the stat case who has developed an acute operative condition within a short time after the ingestion of a full meal.

Of the contraindications, let us mention: (1) Subject with lowered blood-pressure (hypotension). (2) Turbid spinal fluid. (3) Diseases or tumors of the brain, cord, and meninges. (4) Recent syphilis. (5) Intra-thoracic conditions, as (a) very large effusions; (b) *large* growths, especially mediastinal. (6) Advanced toxic or moribund cases of peritonitis. (7) Acute febrile infections, especially acute pulmonary tuberculosis. (8) General sepsis or suppuration near the point of spinal puncture. (9) Finally, where patient cannot stay in bed for twenty-four hours after operation.

If some one drug and some one technic that answered all requirements were found, the ideal state would be reached. The ideal is always our aim, in everything progress is made because the ideal has not been reached, thus our research, our experiments, and our discoveries. Cocaine as a spinal analgesic was found in the broad, main principles, good, but dangerous (1898). Then followed tropococaine, stovaine, novocaine, alypin, syncaïne, each possessing qualities of perfection, each having the broad good principle of analgesia, but each falling short of the perfect, and so we bear them in mind, but still hunt for the more nearly perfect agent. Up until this time we have been rather limited in the operative field, few surgeons operating above the costal border, rarely above the nipple line. Various agents in combination have been tried. Barker advocates a specific gravity heavier than spinal fluid; Babcock especially

a lighter, although he uses a heavier also. Jonnesco combines strychnine, others use chloretone as a solvent, still others, sterile salt solution, and so on.

As to technic, many use Quincke's point, others Tuffier's point, still others, notably Babcock and Jonnesco, have injected opposite the segment supplying the part to be operated. The position of the patient is taken into account, heavier or lighter fluid in the spinal canal may rise or fall, as the case may be, when the patient sits up, lies on one side, prone or in Trendelenburg position. And other variations can be noted in looking over the various methods of administration that have been advocated. The method of having a drug pure, uncombined, and dry, being dissolved in the subject's own spinal fluid immediately before injection, has been mentioned in reports, but has never found the general favor as have the prepared sterile ampules of fluid.

To Dr. Paul Delmas, of the University of Montpellier, France, Chirurgien Consultant Régional of the XVI region, a surgeon active in front war surgery, as well as base hospital work, my friend and teacher, I owe the majority of the following matter in this paper. I will, with his permission, quote liberally from his manuscript copy of a report which he gave me in the spring of 1919.

Quoting: " The greater part of spinal anæsthesia has been confined to a variable upper limit of actual analgesia not ascending perfectly much above the umbilicus. To the work of Lefilliatre by the demonstration of many thousands of cases, we owe this sphere broadened to include the whole body, with a certainty and without risk, by the simple preliminary subtraction of spinal fluid. The height of the analgesia is the function of the fluid withdrawn. The diffusion of the active principle which has produced it, mounts higher in proportion as the resistance is less, which is opposed to its penetration by the volume of the superimposed liquid. As this pressure to be overcome increased with the elevation, any dose whatever obtained a duration so much the more brief with the higher the elevation, or inversely to the anæsthenization of the higher parts, requiring progressively increasing doses."

During the progress of the war, Doctor Delmas employed the procedure of Lefilliatre. Added experience and study led him to modify the technic so as to attain unity of dose with unity of time, whatever might be the height desired.

Instrumentation.—Spinal puncture needle (trocar and cannula), all glass syringe, Luer type, 20 c.c. Needle preferably of platinum-iridium, 7 cm. long, 1.4 mm. diameter, model of Bruneau, the point brought to an abrupt bevel.

Anæsthetic Agent.—" Purified hydrochlorate of cocaine," prepared by Templier, Paris, or by an anhydrous process explained later in this paper. " This cocaine used to the exclusion of all other substitutes which are less active and less diffusible, hence necessitating stronger doses." Co-

caine crystallized, dry, put up in sterile ampules, dissolved at the moment of use in the cerebrospinal fluid of the patient. "Solutions prepared in advance, by reason of molecular action observed, renders them promptly unreliable and injurious, the same is applicable to sterilization, heat altering the physiologic activity of the product."

"The lumbar puncture is performed at a level just above the sacrum" (between the fourth and fifth lumbar vertebræ. Tuffier's point). The syringe takes in 20–25 c.c. of fluid, is detachèd from the needle (trocar being inserted), and the first 20 c.c. thrown away, to have access with a certainty to the higher spaces. The ampule of cocaine, dry crystals to the dose desired (.01–.05 gm.), is opened, the remaining spinal fluid, 3–5 c.c., is put into the ampule and the whole gently agitated. The barrel of the syringe is charged with the freshly prepared cocaine solution, readjusted to the needle, 20 c.c. of new spinal fluid is drawn into the syringe, the whole is thrown forcibly back into the subarachnoid space. The force used is in proportion to the height desired (the higher the more force necessary). "This fluid column of analgesic liquid immediately diffuses in a homogeneous fashion into the remaining spinal fluid which impregnates to the same degree all the posterior roots." The reason of this is that "to the preliminary hypotension created by removing 20 c.c. of spinal fluid, there is added the force of penetration of a relatively large charged mass (over one-third of the remainder)."* All parts, needle-syringe joint, barrel, and plunger of syringe must fit tight, allowing of no leakage whatsoever.

The analgesia of the entire body is instantaneous if maximum force is used. "The other manifestations of sensibility, contact, and temperature, are not necessarily disturbed, conduction of pain alone is interrupted totally independent of the elevation. Duration of .01 gm. equals a minimum of fifteen minutes, this is often exceeded." The quality of analgesia is not altered by size of dose of agent, .01 gm. giving as perfect a result for fifteen minutes as .04 gm. for one to one and a half hours. "The action seems to be confined practically to the posterior ganglions alone, voluntary or reflex action is apparently undiminished. Ideation, circulation, and respiration are little, if any, slower than normal." Blood-pressure is possibly lowered, but not to a dangerous degree. No exact data as to this important condition have been made.

Doctor Delmas reports 431 cases by this agent, the results being: No failures, no mortality, immediate or following, due to analgesia, not even any alarm on the table. After effects, if any, have been very slight and transient. Doctor Delmas ends his report with: "So the procedure is to be employed above all in cases which contraindicate a general anæsthesia, such as those suffering from shock, hemorrhagic, pulmonary, cardiac, albuminuric, diabetic conditions, and in general, all those who are doubtful risks."

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* The amount of spinal fluid in a normal individual is about 70 c.c. Later findings place the amount from 125 c.c. to 150 c.c. Dercum, F. X., Dec. 8, 1919.

"It is contraindicated in local sepsis at point of puncture, general cerebral tumors, fragile vasculatory systems in which one fears an intra-cephalic lesion."

I might add the sterilization of the puncture site is tincture of iodine one-half strength, two coats. Area includes from posterior inferior spine to posterior inferior spine, and from below the upper level of the sacrum to the first lumbar vertebra.

The method of purifying the cocaine has been carried out by Professor Gardin, of the University of Montpellier, together with Doctor Delmas. It consists of dissolving a given quantity of commercial hydrochlorate of cocaine in a given amount of absolute alcohol, recrystallizing by the addition of absolute water-free ether (sulphuric); decanting off the liquid, drying the crystals in a vacuum or a sulphuric chamber. Collecting, weighing, and putting crystals in ampules under sterile conditions. Glass of ampules should be colored preferably brown, size approximately 5 c.c.

In conclusion, my own experience with this anhydrous preparation of cocaine has been one bearing out Doctor Delmas in practically all particulars. The operative range of this analgesia includes operations on the forearm, glands of the neck, wounds of the scalp, and even a trephine. For resection of a rib in empyema or war wounds, it is apparently ideal. Post-operative headache is sometimes complained of, but not for long nor is it excessive in severity. There is no tingling or burning of the feet or legs as at times is met with in, for example, novocaine or syncaine, which agents I have observed used in several of the French clinics.

The posture when injection is made can be either sitting or lying, apparently there is no difference in result, the sitting posture is the more easy of injection. The analgesia is practically instantaneous. The toxicity has not been, to my knowledge, up to this time, worked out for this preparation of cocaine, but in a later report I hope to be able to present this phase.

A spinal analgesic is not an anæsthetic to abolish ether or even to supplant it, but is a very valuable aid to our anæsthetic series, and one, when ether is contraindicated, which may lessen our general surgical mortality.

I should like to add that to import this preparation of cocaine from France has been thus far impossible, but through the kindness and co-operation of Dr. George W. Raiziss it has been produced in the Derma-tological Research Laboratory, Philadelphia, according to the original French formula.

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TRANSACTIONS

OF THE

PHILADELPHIA ACADEMY OF SURGERY

Stated Meeting held January 5, 1920

The President, Dr. George G. Ross, in the Chair

THREE-WEEKS-OLD EXTRA-UTERINE EMBRYO

Dr. Astley P. C. Ashhurst reported the case of a woman, aged twenty-six years, who was admitted to the Episcopal Hospital during the night of August 21, 1919, complaining of pain in the lower right quadrant of the abdomen. Her last menses, which began August 5, were normal. Eight days before admission (that is, August 13) she began to bleed again, and to suffer some abdominal pain. On admission she was thought by the receiving ward interne to have salpingitis, and she was sent to the ward over night. In the morning she appeared slightly anæmic, and a diagnosis of ruptured extra-uterine pregnancy (right) was made. The pain persisted, and there was a very tender mass in the region of the right tube.

On opening the abdomen the presence of free fresh blood confirmed the diagnosis; the right tube was distended and tense with blood, and bleeding from the fimbriated extremity continued. The tube and ovary (and, incidentally, the appendix) were removed, the blood evacuated, and the abdomen closed. Recovery was uneventful.

Section of the tube discloses an embryo (Fig. 1), apparently about three weeks only in age, lying lengthwise in the tube, in the midst of blood clot. The membranes were intact. Evidently tubal abortion was impending at the time of operation.

Dr. W. H. F. Addison, Professor of Histology and Embryology in the University of Pennsylvania, very kindly examined the specimen under the microscope, and reported its length as 10 mm. The cephalic extremity was somewhat crushed, but the limb buds could be detected; they showed no indication of any digitations, nor even club-shaped expansion of their ends. From these data he estimated its age at about thirty days.

SAC OF INDIRECT INGUINAL HERNIA WITH COMPLETE OBLITERATION AT ONE POINT

Doctor Ashhurst also reported the case of a man, aged twenty-six years, who wore a truss for about eighteen months, when a small boy, for right inguinal hernia. Since childhood the hernia had not been down

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FIG. 1.—Very early extra-uterine pregnancy (three
weeks). Embryo lying in a mass of blood clots in
the tube—actual size.

until it appeared as an incomplete indirect right inguinal hernia, after a lifting strain a few days before operation, which was done January 2, 1920, at the Episcopal Hospital. The sac extended below the level of the external ring, and its fundus was distinct from the tunica vaginalis testis. When the sac was opened near its fundus, it was found obliterated about 4 cm. distal to the internal ring. The proximal portion of the sac, continuous with the peritoneal cavity, was then opened, and both portions of the bilocular sac excised; and the inguinal canal was repaired in the usual way (after incidental appendectomy through a McBurney incision).

Doctor Ashhurst remarked that one knows how frequent it is to meet with partial occlusions of such hernial sacs, at one or more levels; and the occurrence of hydrocele of the cord proves that complete obliteration may occur. But the question is, does wearing a truss for eighteen months, or even for eighteen years, produce such an obliteration? It seems very unlikely that it ever does; certainly nothing he had ever encountered in an operation for inguinal hernia indicates that it does; and even granting that this case is an instance of the occurrence, the fact remains that the obliteration occurred not *at the internal ring,* where it might prevent recurrence of the hernia, but in the course of the sac as it passed through the canal, and that the hernia did recur in the proximal portion of the sac.

ABNORMAL DRAINAGE FOLLOWING CHOLECYSTOSTOMY

Dr. Edward B. Hodge reported the case of a woman, a patient of Dr. A. B. Gill, who was admitted to the Presbyterian Hospital July 12, 1916, with history of removal by Doctor Gill of a subacute appendix four years before. For the past ten months there had been attacks of pain in the epigastrium, radiating into the back and right shoulder at times, nausea, vomiting, and epigastric tenderness. When seen a week before, there was slight jaundice. No fever in this or previous attacks. A diagnosis of cholecystitis had been made and operation decided on when jaundice subsided. Although this was still present, pain was so severe as to demand relief.

Under gas-ether an enlarged, rather thick-walled gall-bladder was exposed. It was adherent to the omentum. Stones were felt in the gall-bladder but not in the common duct. The foramen of Winslow was open. The gland at the junction of the cystic and common ducts was enlarged as also the pancreas. The stomach and duodenum were normal. Difficulty in relaxing the patient prevented good exposure, so drainage rather than removal of the gall-bladder was done. There were many dark green stones and the mucous membrane was moderately inflamed, but not of the " strawberry " type. A tube was placed in the gall-bladder and a cigarette drain to the kidney pouch.

For forty-eight hours she did well. In the first twenty-four hours there was drainage of more than a pint of bloody mucus and bile, later

becoming green. For the first fifteen hours of the second twenty-four there was no drainage. On the evening of this day, the fourteenth, drainage became free again, and by evening of the fifteenth amounted to 70 ounces (2100 c.c.) of turbid fluid with some flakes in it. Temperature was 100°, abdomen soft, passing flatus, stomach a little unsettled, and pulse weaker and 120. She was beginning to feel very weak and prostrated. The weather was extremely hot.

From this evening to the next morning the amount of drainage was 1050 c.c. of the same character. Her condition was now alarming with small weak pulse, extremities cold, clammy and bluish, face yellowish, but lips a good color, breath not bad, and no acetone in urine which had become very scant in the last twenty-four hours. Stimulation was increased and saline given under skin in addition to the glucose-sodium bicarbonate solution that had been used by rectum. At this time Doctor Jopson saw her in consultation. The question of attempting to check the excessive drainage from the gall-bladder was discussed, since her condition seemed to be largely due to great loss of fluid by this channel. A clamp was placed on the tube and from that time no fluid came from or around the tube.

By the next morning the patient's condition was decidedly improved, she had had a restful night and felt better. She had passed only 6 ounces of urine in the last twenty-four hours, but this was entirely negative. The tube was removed four days later and replaced by a gauze strip. There was thereafter no leakage. She was discharged from hospital two weeks from operation and has remained in excellent health since.

Colon bacillus was cultured from the gall-bladder at operation. The laboratory report on the yellowish, turbid, flaky fluid at the time of the greatest amount of drainage showed unexpected findings. Tests for bile acids and bile were negative. The fluid did not digest egg albumin or starch and therefore contained no pancreatic ferment. Quantity not sufficient for lipose test.

It is readily seen that the unusual features in this case are the amount and the source of the drainage. The amount of discharge, if from the liver, far exceeded anything he had found recorded in the literature or in the experience of those with whom he had discussed it. The normal daily production of bile is usually given as from 700–900 c.c. In this case there was once 2100 c.c. and again 1020 c.c. for some fifteen hours.

In the absence of positive findings for bile and bile acids, we are led to seek other possible sources. There was no evidence at operation of communication between gall-bladder and stomach, duodenum or colon. Nor was there any reason for post-operative development of such communication. Back flow from the duodenum through a relaxation of the common duct sphincter also seemed ruled out by the laboratory findings. Of one thing we can be sure—the drainage came through a tube sutured into the gall-bladder. In the reporter's opinion the drainage had its

origin in the liver, even though for some reason the ordinary tests for bile were not positive.

ANHYDROUS COCAINE SPINAL ANÆSTHESIA

DR. JAMES RALSTON WELLS read a paper with the above title, for which see page 504.

ULCERATIVE CYSTITIS

DR. FLOYD E. KEENE read a paper entitled " Circumscribed Pan-mural Ulcerative Cystitis," for which see page 479.

DR. JOHN G. CLARK paid a tribute to Dr. Guy Hunner for having discovered and brought this unique pathologic entity to our knowledge. As the report of these cases from the Gynæcological Department of the University Hospital will show, they have all been of chronic standing and the patients have suffered in many instances so excessively that they have become chronic invalids, the dysuria and frequency of urination being so great as practically to confine them to their homes. All surgeons in years past have persistently treated cases of this type under the diagnosis of chronic cystitis, and yet neither the cystoscopic picture nor the urinalysis bore out this diagnosis. The case that brought this type of pathology to his cognizance was the first one to which Doctor Keene alluded, of a woman who had been under observation for fifteen years for an extensive cystitis following an abdominal operation. Gradually all of the characteristic clinical findings of cystitis disappeared but the symptoms persisted and even grew worse. After several ineffectual operations of various types and the employment of every manner of treatment the patient fell into Doctor Hunner's hands, who promptly made a diagnosis of solitary ulcer, and, after she had undergone the operation which he has devised for this condition, she regained her health completely.

These cases in their variation between acute exacerbations and temporary quiescence are suggestive of the manifestations of a duodenal ulcer. Also, the symptoms are out of all proportion to the diminutive lesion which one discovers on cystoscopic examination. The lesion, therefore, is an extremely small one, but the symptoms are decidedly major in severity. When one views these small ulcers and contemplates the major operation necessary to relieve the patient the therapeutic procedure unquestionably appears to be out of proportion to the existing pathology. Nevertheless, as the results have demonstrated, there is no series of patients more grateful for their relief than these, and count the operation of small significance when they have experienced complete relief. It is to be hoped that the time will come when some other form of treatment may be instituted which may obviate so extensive an operation. Nevertheless, Hunner has given these cases the most painstaking and skilful attention, and finally through failure of local treatment to achieve favorable results, he was compelled to resort to operation. In view of

the fact that Hunner has so well defined and described this condition, there need be no great difficulty in naming the condition. We have chosen, therefore, to designate this as the Hunner Ulcer, for we feel that through his careful work he deserves this identification.

DR. ALEXANDER RANDALL said that since his attention had been drawn by Doctor Keene to this type of bladder ulcer he had been looking for it in the male, but had not thus far met with it. He had asked Doctor Keene as to the possibility of the condition being tuberculosis. The ulceration of the bladder, the sterile urine cultures, and the chronicity highly suggest tuberculous origin. He replies that in repeated examinations cultures in guinea pigs have been negative as well as studies of section of excised tissue. He cannot, however, help feeling that search should be continued along this line, because as pointed out by Pelouse there has been obsrved another unusual form of tuberculosis in this region. Surgeons are still very much in ignorance of the actual pathology and physiology of the bladder itself, especially as regards infections.

MALIGNANT DISEASE OF THE LUNGS

DR. GEORGE E. PFAHLER read a paper with the above title, for which see page 472. The paper was illustrated by lantern slides.

TRANSACTIONS
OF THE
NEW YORK SURGICAL SOCIETY

Stated Meeting held January 14, 1920

The President, DR. WILLIAM A. DOWNES, in the Chair

TUBERCULOSIS OF THE CHEST WALL

DR. WALTON MARTIN presented a man twenty-four years of age who was admitted to St. Luke's Hospital in January, 1917. At that time he was a well-nourished young man with a discharging sinus in the mid-axillary line on a level with the eighth rib and a soft fluctuating tumor over the fifth rib. He was operated on by Doctor Derby. The sinus was dissected out and portions of the eighth and ninth ribs removed. The wound was left open and irrigated with Dakin solution and two weeks later an attempt made to close it by secondary suture. The wound, however, never healed entirely, and the patient left the hospital with two sinuses, one discharging anteriorly and the other posteriorly, and was running a little temperature.

On May 17th he returned to Doctor Martin's service still with his discharging sinuses and obviously not in as good condition as he had been, having an afternoon temperature and having lost weight. An extensive operation was performed, an " H " shaped incision being made, the two long arms of the " H " passing through the sinuses and the horizontal portion passing between them. The flaps were dissected back and the fifth to the tenth ribs resected with the overlying parietal pleura.

Pathological Examination.—Extensive tuberculosis of the ribs removed and of the pleura. The young man improved for a while. The extensive wound healed except for two fistules, one anteriorly and one posteriorly. From time to time he ran an afternoon temperature.

X-ray examination showed much thickening of the pleura and poor expansion of the lung. It was evident that there was a tuberculous process still present which had not been removed, even by the extensive operation.

On July 5th, portions of the sixth, fifth, and fourth ribs were removed well back to the spine. The wall of the chest and the parietal pleura forming the roof of the cavity were removed. This cavity, about the size of a fist, was filled with pus, the lung was collapsed and pushed upward and backward. A strip of the visceral pleura was resected in an effort to allow the lung to expand.

On October 16, 1917, a sixth operation was performed, removing portions of the second, third, fourth, and fifth ribs as far forward as the

costal cartilages. This again exposed a cavity in the pleura containing pus, but the incision of the ribs and the anterior part of the chest wall merely obliterated this cavity. From this time on the boy improved, and the wound healed by primary union except for one granulating area in the region of the second rib, which led to a sinus extending upward to a small cavity apparently near the apex of the lung. He was kept under observation, under as good hygienic conditions as possible, and the sinus cauterized with pure carbolic from time to time. He gradually gained weight and strength, the sinus closed last June, and he is now well and able to earn his living.

Doctor Martin said that he had presented the patient as he showed a favorable outcome from apparently a very hopeless condition of extensive tuberculosis of the ribs, which had extended to the neighboring pleural cavity and had become secondarily infected, causing a chronic empyema. Curiously enough, there was no evidence at any time of a second tuberculous focus elsewhere in the body.

TREATMENT OF MYXŒDEMA BY TRANSPLANTING PORTIONS OF A HYPERPLASTIC THYROID GLAND

DR. CHARLES N. DOWD presented a woman, aged forty-seven years, who was admitted to the Roosevelt Hospital May 16, 1919, on account of myxœdema. Four years before she had been a telephone switchboard operator and was then able to do the rapid work incident to that occupation. Her mental processes and her speech had gradually become very slow. She had frequent dizzy spells, dyspnœa on slight exertion, puffiness below the eyes, and a dull expression in face. Her skin was thick and dry. Her hair was falling out rapidly and what remained of it was very dry. Her finger nails were also thickened. The thyroid was not palpable.

Another patient was in the ward who had hyperthyroidism. This presented a particularly good opportunity for transference of thyroid transplants from a patient who had too much thyroid activity to one who had too little, and accordingly this was done on May 24.

The gland which was removed was manifestly hyperplastic and made an excellent specimen for grafting. During operation, an opening was made in the cancellous tissue of the head of the left tibia about one-half an inch wide and one-half an inch deep. The oozing was carefully stopped in this pocket by gauze pressure. The piece of thyroid was cut to fit it and was introduced so as to apparently fill it completely. The periosteum was then sewed over it and the skin sewed over the periosteum. An incision had also been made in the lower part of the left rectus muscle through the rectus sheath into the properitoneal tissue. Seven or eight pieces of the excised thyroid gland, about one-eighth of an inch by one-quarter of an inch in their diameters, were inserted into this properitoneal tissue and the rectus sheath reunited with catgut in front of them. Six or eight other similar pieces of thyroid tissue were

then implanted in the abdominal wall in front of the rectus, and the skin closed with silk suture. About fifteen small punctures were made in other parts of the abdominal wall and little pieces of thyroid tissue were inserted in them and the punctures closed with silk stitches.

Recall Notes.—July 13, 1919: Patient feels very much better. More energetic and active. Speech much improved. Dizzy spells on sudden motion returned about two weeks ago. Has gained 12 pounds. Good appetite. Bowels good. No thyroid extract since operation.

September 28, 1919: Gained 30 pounds. Eyesight greatly improved. Hair growing rapidly on scalp. Speech improved. Appetite fine. Skin still dry. General health excellent.

October 5, 1919: Speech better. Voice lower. Skin more moist. Hair returning. Skin not so thick.

November 9, 1919: Feels very much improved. Good appetite and digestion. Bowels fair. Weight about the same. Dizziness and speech better. Taking tonic for about two weeks, no thyroid. Desiccated thyroid prescribed, gr. ¼ t. i. d.

January 10, 1920: Improvement continues. Her mental activity has returned. She has good strength and takes an active and intelligent interest in various affairs and in domestic work. Her skin has softened and the dryness has disappeared. The thickness below the eyes has disappeared. Her hair has grown thicker and less dry. The symptoms of myxœdema have almost disappeared.

Dr. Howard Lilienthal asked if he understood correctly that the patient with myxœdema was taking thyroid extract at the present time. If so, why? Was it because she was backsliding before the administration of the thyroid was begun? If not, why was she taking it? He suggested that as so many thyroid transplants had been put in, one be removed to see what had become of it. Doctor Lilienthal stated that he had made a transplant from an animal and it was absorbed. In skin transplants it had been found to be an advantage to get as nearly the same blood chemistry in the two individuals by making blood-grouping tests, and it occurred to him that this was a good place to bring out the same point in connection with making thyroid transplants from one patient to another. Whether transplants were made of skin, thyroid, or any other organ it was important to see that the blood chemistry of the two individuals was not incompatible. In making such transplants there were a good many other factors to be taken into account both in transplanting from one human being to another and in making autogenous transplants. Carrel had made a study of transplants from one species to another and found that there was always absorption of the tissue by the host.

Dr. Walton Martin said that while he was in Cleveland several months ago he had seen in Professor Marine's laboratory a number of rabbits in which the thyroid had been transplanted. The autogenous grafts grew well, but the grafts from one rabbit to another grew for a time and then slowly disappeared. Doctor Martin stated that Prof. Marine was attempting to carry out Doctor Lilienthal's idea of making some sort of blood grouping.

Dr. John Douglas said that what he wished to say was related to skin grafts rather than to thyroid transplants, though it might have a bearing on the latter in relation to autolysis of transplanted tissue. Within the last six months, he said, he had made a number of skin grafts on a patient and found that it was necessary to make still further grafts. He had the patient's blood tested out with that of her brother's and found the grouping exactly the same. He then used skin grafts from the brother and while the grafting was not followed by infection and the grafts did well for about ten days and appeared to take perfectly, by the end of three weeks they had gradually autolyzed, and this without any suppuration. He subsequently made grafts from the patient's own skin and they all took and healed perfectly.

Doctor Dowd, in closing the discussion, said as to the thyroid transplants, he had not at first taken the matter very seriously and had not believed that they alone would be able to permanently and sufficiently carry on the thyroid function. The occurrence of two patients side by side, one with hyperthyroidism and the other with thyroid deficiency, gave a particularly good opportunity for trying the transplant. The subject had been well worked out and was recorded in the literature. The reports indicated that a certain degree of improvement could be expected and that sometimes it had lasted for a very long time and that excised transplants had shown active blood supply. After the operation, this patient disappeared and was not seen during the summer. When she was seen in the fall her improvement was really remarkable. She had suffered no relapse, but it certainly seemed wise to give her desiccated thyroid by the mouth to insure the continuance of the improvement. The result of the operation had certainly been very satisfactory and if she should have a relapse and another hyperactive thyroid could be obtained, a repetition procedure would be justified. The question of blood grouping had been considered and he hopes to work it up at a later time.

TREATMENT OF OBLIQUE FRACTURE OF THE FEMUR BY BINDING WITH CHROMIC CATGUT

Dr. Charles N. Dowd presented a girl of five years, who had sustained a fracture of the thigh on September 29th, and had been treated by the application of a long plaster-of-Paris spica.

On October 4th, the X-ray indicated overriding and faulty position; and measurement, with plaster removed, indicated shortening of one inch. Effort was made to overcome this shortening by strong traction. Vertical suspension was then applied to the legs so as to raise the buttocks from the bed. This procedure did not meet with the ordinary success. The shortening and overlapping remained.

On October 20th she was anæsthetized. Traction and manipulation were unsuccessful. The overlapping fragments were therefore exposed

by operation. The fracture was oblique, two and three-quarter inches long, just below the middle of the femur. There was a very large amount of callus. Apparently, the rapid formation of the callus had prevented the success of the previous traction. When this callus was removed and traction applied by the aid of the Hawley table, anatomical apposition was easily obtained.

It is difficult to apply Lane's plates to a small bone for an oblique fracture as long as this, but very easy to apply some form of binding, hence five wrappings of chromic gut were passed around the bone near each end of the fracture. A half-hitch was taken with each wrapping and the ends were so tied as to tighten it all. The resulting support was remarkably good. The fragments fitted accurately into each other and after they were bound in this position the firmness of the bone was most satisfactory.

A supporting spica of plaster-of-Paris was then applied from the costal border to and including the foot and the patient returned to the ward.

The technic of the procedure was shown in the accompanying diagrams. Doctor Dowd stated that an ordinary uterine sound could be filed into a crochet needle and bent into the desirable shape, or a " Parham Band " passer may be used. The chromic gut might be passed and fastened by instruments without contact with gloves (Lane technic) if one so desires.

X-ray pictures taken three days after the operation showed accurate anatomical apposition; those taken ten days after the operation showed a very slight bending of the bone; those taken after another week showed a little more bending but no shortening. The chromic gut, together with the plaster-of-Paris dressing, were sufficient to hold the bone fragments until they united in satisfactory position. At the present time there was good union with no shortening, but with moderate anterior bowing of the femur.

The method used for this patient must have a very limited application. It did not give as lasting support as metal plates did and hence was not reliable. It was, however, much easier of application to long oblique fractures. It avoided the late discomforts which occasionally come with metal plates and in this case, at least, it held the bone as long as was necessary.

DR. ROYAL WHITMAN did not approve of the method of treatment described by Doctor Dowd. In his opinion, a plaster spica would not, as a rule, prevent overriding of the fragments, while perpendicular traction aside from its discomfort must lessen the blood supply and thus delay repair. He thought the most satisfactory treatment for fracture of the femur in childhood was, having adjusted adhesive traction straps to the limb, to completely reduce the shortening under anæsthesia. A closely fitting plaster spica was then applied, and this was

supplemented by a sufficient traction weight to prevent displacement by muscular action.

Dr. H. B. Delatour stated that he had used catgut on the clavicle where there was an oblique fracture and overriding, and a possibility that the sharp ends of bone would puncture the skin. By wrapping the clavicle with catgut he had obtained very good results. He was not certain, however, that the results would be so satisfactory in the femur.

Dr. John B. Walker stated that he had abandoned the treatment of fracture of the femur by suspension because he had obtained the same unsatisfactory result so often. He felt that one could not rely upon suspension.

Doctor Dowd, in closing the discussion, said that he was glad the question of treatment of fracture of the femur by a plaster spica had been raised. He agreed heartily with the statement that this catgut wrapping was not an efficient treatment unless the fragments were also held together by some other means. He had looked at it with suspicion when its use was being advocated. Later results had proven that the plaster spica could not be depended upon to maintain the fragments in suitable apposition. The case which he had shown had already been thus treated when it came under his care and the callus which had formed during that period probably prevented the suitable lengthening of the leg after the suspension treatment was used.

On the other hand, the treatment of fracture of the femur by suspension had proven very satisfactory for young children, but had not been efficient for children older than five or six years.

The case had been brought before the Society to illustrate the way in which the chromic gut binding had proved efficient in this particular instance. The method had a very limited application. It could not be relied upon to hold the fragments for more than ten days and should only be applied for long oblique fractures; and the fractured bone should be supported by an external appliance so as to maintain the position after the chromic gut has begun to loosen.

INJURY TO LOWER EPIPHYSIS OF THE TIBIA
(Five years after accident)

Dr. H. Beeckman Delatour presented a boy who was admitted to St. John's Hospital, Brooklyn, five years ago, and was ten years of age at that time. He had sustained an injury to his ankle. While climbing on a picket fence he had fallen, catching his foot between the pickets and twisting his ankle. He presented all the signs of a fracture of the ankle at the lower end of the tibia. Doctor Delatour presented the X-ray plate taken at that time, showing a slight degree of displacement internally at the lower end of the tibia. The ankle was put up in a plaster case and at the end of four weeks a second X-ray, which Doctor Delatour exhibited, was taken which showed that the boy left the hospital with his

ankle in absolutely perfect condition, without any deformity. At that time all the movements at the joint were perfectly normal. The boy wore the case for a week after leaving the hospital; it was taken off at the end of the fifth week. After this the boy went along apparently in normal condition for three years, when his mother noticed that his foot was beginning to turn a little. The deformity then gradually became more marked and from that time he had had the deformity which he now presented. As could be seen the whole foot was thrown inward and there was about an inch shortening of the limb. There was the same amount of shortening if one measured the tibia itself. The boy, Doctor Delatour said, went about with perfect ease but the deformity was increasing. Another X-ray plate taken a month ago showed what had taken place. The inner one-half of the tibia had not developed while the outer one-half had developed in the normal manner, with the result that there was a turning of the foot inward and a corresponding change in the upper surface of the astragalus.

This case was interesting because the injury was not the result of a direct blow, but of twisting, and because the injury had been to the epiphysial line of the tibia. The question was what could be done to prevent further progress of the deformity. As was well known ossification was not complete until the eighteenth or nineteenth year, and in the fibula it was a little later. If there still remained a period of three or four years during which these bones might grow a much greater deformity than he now had would develop. Occasionally there were two points of ossification in the lower end of the tibia and the question had suggested itself to his mind whether the internal one alone was injured. This case was also interesting from the standpoint of prognosis. Any one who saw the boy at the time he left the hospital would have said that the result was perfect. Again it is rare that an injury to the epiphysis produces shortening, but this case shows what might happen. The boy had consulted an orthopedist, who drew a diagram of the condition showing that the boy had sustained an oblique fracture which pushed the inner one-half of the tibia upward. He stated that an osteotomy was indicated to straighten the leg.

This case might also be interesting from the medico-legal standpoint in that it might lead to a lawsuit for damages if one did not have the X-ray plate to show that the result was perfect at the time the boy left the hospital.

DR. ROYAL WHITMAN said he had seen several cases of this type. In this instance, as the patient was well advanced in adolescence, the prognosis as to the final result should be good, since there was but slight varus and a full range of motion in the ankle-joint. The disproportionate length of the fibula did not as a rule interfere with function, and eventually the lateral deformity might be permanently corrected by osteotomy.

APERIOSTEAL, SUBTROCHANTERIC AMPUTATION OF THE THIGH

Dr. Henry H. M. Lyle presented a boy who, twelve years ago, had a fracture extending into his knee. The fracture resulted in an infection of the knee-joint and an osteomyelitis of his femur and tibia. In the course of these twelve years he has had ten operations in four different hospitals. Finally he was referred to Doctor Lyle's service at St. Luke's for a disarticulation at the hip.

The condition at admission was that of an active osteomyelitis of the femur, with destruction of the knee-joint and numerous discharging fistulæ of the thigh. The X-ray plate, Doctor Lyle said, showed the amount of bone involvement. It would be noted that it extended to within two inches of the trochanter.

Knowing the difficulty in getting a good working artificial leg for a disarticulation of the hip, Doctor Lyle decided to do a subtrochanteric amputation of the hip, and to try for an end-bearing stump. An external racquet incision was employed and the bone sawed through one inch below the trochanter. The flaps were left open and the wound treated by the Carrel-Dakin method and traction. Sterilization was obtained and a secondary suture of the wound performed. The patient was then placed on the stump exercises, and two weeks after the closure of the wound was fitted with a temporary bearing peg leg.

X-ray examination of the stump showed it to be perfectly smooth.

The boy was later fitted with a permanent artificial leg. He had been wearing this leg ever since the operation, more than three years ago. It could be seen how well he walked; in fact, for some time, he was a demonstrator and teacher in the use of artificial legs.

Doctor Lyle said his object in showing the case was to demonstrate the value of short bony stumps, and to show that, far from being a useless operation, the aperiosteal subtrochanteric amputation of the thigh had a definite place in surgery, as it gave a superior functional result.

Doctor Lyle said he had performed five subtrochanteric amputations—two in this country and three abroad. The other one done in this country had been shown before this society. All five had had good functional results; which went to show the incorrectness of teaching that this operation is useless unless you can save at least three inches of the bone below the trochanter.

IMMEDIATE ACTIVE MOBILIZATION OF THE WRIST-JOINT FOLLOWING EXCISION OF FRACTURED SCAPHOID

Dr. Burton J. Lee presented a young man, nineteen years of age, who had been in the service abroad. Doctor Niles had originally seen this case. The patient had sustained an injury to the wrist while playing football, but had lost no time from duty in consequence. However, the wrist had shown moderate disability which had been present from the receipt of

the injury up to the time when Doctor Lee first saw the case, which was five weeks ago. The joint was tender over the scaphoid region and there was slight general swelling of the whole wrist. Motions of the joint elicited slight pain which was very much increased by extreme flexion. The boy had, however, continued to play football and hockey with the wrist partially immobilized by an adhesive plaster bandage. Doctor Lee showed the X-ray plates taken by Doctor Imboden. The diagnosis lay between disease of the scaphoid (bone cyst or tuberculosis), a primary fracture of the bone or a fracture following disease of it. It was finally concluded that the diagnosis and relief of symptoms could be only made with open operation.

Operation was performed through a dorsal incision and the scaphoid removed. The bone had been fractured, the two pieces being glued together with loose cellular tissue. The wound was closed and treatment by immediate active mobilization carried out. Perfect function had not yet been fully restored, extension still showing about ten degrees of limitation while flexion was fifteen degrees less than normal. The patient was able to firmly close the fist, but the strength of the hand was still slightly impaired. A tremor, intentional or unintentional, had been present during the entire post-operative period, when the patient attempted to close his fist, but this has steadily diminished until now it is but scarcely noticeable.

Although the X-ray findings strongly suggested a bone cyst, the pathological examination made by Doctor Elser did not confirm this impression. Gross and microscopical examination of the bone showed no evidence of bone cyst or tuberculosis, but the bone presented simply a fracture with a certain amount of cellular tissue interposed.

This case illustrated very well what could be done by the Willems method of active immediate mobilization in civil joint surgery.

DR. EUGENE POOL said there were two points that stood out particularly in Doctor Lee's patient; the first was the treatment of compound fractures and the second was the treatment of suppurating joints. In regard to the compound fractures, DePage was the first to emphasize strongly that in compound fractures caused by accident, such as those usually encountered in civil practice, débridement should be carried out and the wound should be closed. At first our surgeons abroad were loath to treat these cases in that way, but they soon became convinced that it was the proper method. Since his return from France, Doctor Pool said he had had four cases of compound fracture on his service at the New York Hospital. Of these two were fractures of both bones of the leg, one a fracture of the lower third of the femur and one a fracture of the humerus. All of these were treated by incision, excision of contaminated and devitalized tissue, and primary suture. In one there was a slight superficial infection which did not reach the bone nor delay repair. The others remained clean. Another point in regard to compound fractures was that after the thorough removal of devitalized and contaminated tissue through an incision of

adequate length and reduction of fragments, if one found it practically impossible for mechanical reasons or inadvisable by reason of probability of infection to do a primary suture, then it was best to leave the wound open, treating it with or without the Carrel method, according to indications. If one used the Carrel method it should be carried out in accordance with all the niceties of the technic, making of cultures, etc. In such cases it is important that the wound be sutured as soon as susceptible of closure, because any compound fracture, if left open too long, in general more than about a week, is likely to become infected and osteomyelitis to result. Probably enough had been said regarding the Carrel-Dakin treatment, but he felt that the point should be emphasized that those who did not get good results with this method probably were not using it in the right way.

In regard to the treatment of suppurating joints, he has found that in early cases with little or no bone involvement Willems method gives admirable results in the knee-joint, which lends itself as a result of its structure to evacuation of the exudate by active movements. If the infection reached the cancellous bone prolonged osteomyelitis was apt to result.

DR. JOHN F. CONNORS referred to the treatment of compound fractures. He stated that during the past three months he had had four cases of compound fracture. The first case he closed and later had to reopen; the others he had treated with the Dakin-Carrel method, closing them at the end of two weeks, when the field was free from bacteria. In his opinion the later closing was the safer and better plan.

As to Willems treatment, during his last eight months in France, he saw and carried out this method wherever possible and could vouch for its efficacy. At this hospital centre many of the cases that came back splinted developed osteomyelitis, while the cases where the Willems treatment had been used were always in very much better condition.

During the past few months there had been two cases on his service treated by Dr. Moorhead, in which this method was employed with most satisfactory results; both of these cases left the hospital with perfect function. The method of mobilization which Doctor Lee applied to the wrist case, in his opinion, could be applied to almost all fractures, and he felt that the day was not far off when it would become common practice to use mobilization instead of immobilization in our treatment of fractures.

DR. H. H. LYLE expressed his firm adherence to the belief that they had in the Carrel treatment the most effective method of dealing with infected wounds. He stated that he was surgeon-in-chief of one of the earliest ambulances to adopt the Carrel-Dakin treatment in its entirety —if not the second, they were the third. It was a question whether they antedated LaPanne or LaPanne antedated them, it all being a matter of a few days. He was a firm believer in the Carrel-Dakin method and practiced it rigidly for over four years.

Regarding the treatment of joints, Doctor Lyle believed that if the closed method could not be employed, the next best treatment was that developed by Willems. He had had considerable experience with the method, and could testify to its efficacy if thoroughly carried out. For some reason or other he had not been so successful in suppurative ankle-joints, and he attributed this to the fact that movement in this joint did not increase the drainage to the extent that the same procedure did in the knee-joint.

Regarding the use of Carrel-Dakin in civil life, it was Doctor Lyle's practice to treat all infected abdominal wounds, as well as broken-down pyosalpinx wounds, suppurative wounds coincident with a drained appendix, and other conditions, with Carrel-Dakin's. In over 85 per cent. of the cases they had been able to perform a secondary suture. The method not only yields stronger abdominal walls, but materially shortens the patient's stay in the hospital.

Doctor Lee, in closing the discussion, stated that the ankle and the wrist lent themselves less favorably than did other joints to the Willems treatment. The results in the ankle-joint were the poorest and those in the knee-joint the best. He thought Doctor Pool and Doctor Lyle had explained the reason for this, namely, that motion gave more effective drainage in the knee than in other joints, so that the method was particularly applicable to the knee-joint.

BOOK REVIEWS

RAMBLING RECOLLECTIONS. An Autobiography by A. D. ROCKWELL, M.D.
Octavo, Cloth, pp. 332. Illustrated. New York, Paul B. Hoeber, 1920.

Dr. Rockwell has placed the medical profession of America under distinct obligation by this interesting volume of reminiscences which extend over a long life of eighty years, beginning in 1840, and thus including a period of wonderful changes, intense activities and unparalleled development in every phase of life, in all of which the author himself has borne no mean part. The book is all the more interesting since it records phases of personal and individual life quite different from those which have been the basis of other biographies and autobiographies which have recently been given to us.

The earlier chapters give a charming view of a childhood and early youth in a Connecticut village. The gradual transition through college days and Civil War experiences into the condition of a practitioner in a new specialty in the metropolis is detailed in a series of sketches that hold the interest of the reader to the last paragraph. It is the story of his life told in his old age by one who still retains his mental vigor and who has a story to tell that is worth telling.

The chapters which constitute Book III, which give his experiences as a trooper with Sheridan, differ from the usual tales of an army surgeon in that they are not pictures of hospital life and of surgical events and needs, difficulties and disasters, but of work done in the saddle on many bloody fields, of dangers constant and perils oft, and of fatigues and labors, of marches and counter-marches with the most energetic and daring of the cavalry leaders that the Civil War produced. Appointed surgeon of the Sixth Ohio Cavalry early in 1864, Rockwell was at once caught in the maelstrom of war and during the terrific contests that Grant waged with the Army of the Potomac during the last year of the war, he was a part of the mighty stream that flowed relentlessly on to the final plunge at Appomattox. The battles of the Wilderness, of Cold Harbor, the beleaguer of Petersburg, the reunion with the forces of Sheridan and the final dash around to the rear of Lee's Army, followed by the decisive battle of Five Forks, and the final coming out from the ranks of the enemy of the white flag of surrender, these are all graphically described by one who was a part of it all.

It was a great change from such activities, in which men were sustained by a kind of exaltation, to the position of a young doctor trying to conquer a place for himself in civil life and practice. He struggles— he marries—he adopts a specialty—he becomes an author—he succeeds. The lights and shadows of all these days form the rest of his story. Not

the least interesting chapters of this part of his book are those in which he narrates what he saw of many of the eminent men of every walk in life with whom his later work brought him in contact. We have read every word of the book, held by the charm of the story until an early hour of the morning, and lay it down thankful to the author that he has written it.

LEWIS S. PILCHER.

MODERN SURGERY, GENERAL AND OPERATIVE. By J. CHALMERS DACOSTA, M.D., Samuel D. Gross Professor of Surgery, Jefferson Medical College, Philadelphia, Pa. Eighth Edition, Revised, Enlarged and Reset. Octavo, 1697 pages. Philadelphia and London: W. B. Saunders Company, 1919.

The reviewer has before him the first edition of DaCosta's Manual of Modern Surgery, a handbook of small size, published in 1895, and which at that time served as a helpful and practical guide in preparing the writer and others for final examinations at the medical school and competitive tests in surgery for a hospital internship; it is therefore remembered with special interest and appreciation.

Through various editions this volume has had long continued and increasing popularity as a standard surgical text-book and now the eighth revised and enlarged edition appears as an octavo of 1697 pages with 1177 illustrations; truly an enormous undertaking for a single individual during a period when such efforts have been largely superseded by coöperative or joint editorialship.

In this work are presented concisely the views and opinions of a veteran teacher of vast experience and sound surgical judgment and with it all he has reviewed and included the best of other modern surgical thought and opinion.

In the preface the author refers with some apology to the difficulties of revision under war conditions and yet the chapters on the newer methods of treatment in wound infections, compound fractures and injuries of the head and chest form the most noteworthy contribution to the revised edition.

The author's personal experience and opportunities for observation made it possible for him to include authoritative sections on the Carrel-Dakin technic, the most recent advances in the prevention and treatment of tetanus and gas gangrene and the now generally accepted methods in the management of fractures and osteomyelitis and kindred lesions due to the wounds of war.

The remainder of the text has been brought thoroughly up to date even though lacking in much of anything that is new as compared with the previous edition.

Opinions are expressed in several parts of the text about which there will be honest differences of thought and practice among surgeons; for

instance, in his discussion of empyema thoracis, and contrary to the now generally accepted modern idea and experience, the author does not believe in "delayed" or "late" operation but continues to maintain that collections of pus in the pleural cavity should not be temporized with but that adequate provision for drainage should be provided as soon as the condition is recognized regardless of a coexisting pneumonia or the general condition of the patient.

In holding this opinion he will not have the support of many surgeons who had a large experience in the management of empyema in the military hospitals including the Empyema Commission. His opinion will, however, agree with the teaching of the War Demonstration Hospital of the Rockefeller Institute and it remains for the reader to draw his own conclusions.

There are forty-one well arranged chapters in all; there is a satisfactory index and the illustrations are well selected and helpful in the interpretation of the text.

This work is worthy of the continued confidence of both students and practitioners of surgery and we predict for it the same demand and popularity with which former editions have been received.

WALTER A. SHERWOOD.